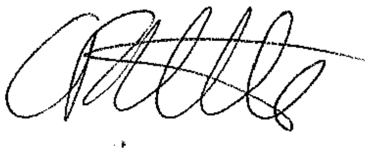
Testing and Applying the MarHADS Tool in the Auckland Council Region

February 2014 Technical Report 2014/004

Auckland Council
Technical Report 2014/004
ISSN 2230-4525 (Print)
ISSN 2230-4533 (Online)

ISBN 978-1-927302-23-1 (Print)
ISBN 978-1-927302-24-8 (PDF)

This report has been peer reviewed by the Peer Review Panel using the Panel's terms of reference
Submitted for review on 7 November 2013 Review completed on 19 February 2014 Reviewed by two reviewers
Approved for Auckland Council publication by:  Name: Greg Holland Position: Manager, Research, Investigations and Monitoring
Date: 19 February 2014

Recommended citation:
MacDiarmid, A B; Stenton-Dozey, J and Roulston, H (2014). Testing and applying the MarHADS tool in the Auckland Council region. Prepared by NIWA for Auckland Council. Auckland Council technical report, TR2014/004

Testing and Applying the MarHADS Tool in the Auckland Council Region

Alison MacDiarmid
Jeanie Stenton-Dozey
Helen Roulston

National Institute of Water and Atmospheric Research Ltd

Executive Summary

Over the period 2008-2011 the Marine Habitat Assessment Decision Support (MarHADS) tool was jointly developed by NIWA and a team of regional council coastal scientists and planners (including Auckland Council staff) to assist regional council resource managers and decision makers to critically assess the relative state and value of coastal habitats. It was envisaged by the participating councils that standardisation of the assessments through application of the tool would enable comparison of habitat values within and among regions and at a national level. To-date no council has used the MarHADS tool to assess any marine habitats.

In March 2013 NIWA was engaged by Auckland Council (AC) to test and apply the MarHADS tool, and to develop and apply a methodology to combine the individual habitat scores for a sub-region, such as a harbour, estuary, or bay. This was the first opportunity to explore the capabilities of the tool. The approach taken was deliberately interactive with two workshops with AC staff to ensure relevant data were available; jointly undertake some initial assessments; develop an approach to combining assessments; and, through reviews by AC staff of a subset of preliminary habitat assessments undertaken by the NIWA team, develop consensus on scoring habitats.

The MarHADS tool was applied to habitats across five estuaries along the western fringe of the Hauraki Gulf. These estuaries (Whangateau, Mahurangi, Puhoi, Waiwera, and Tamaki) were chosen because there were good data sets available on some of the important habitats, and because they were thought to lie along an impact gradient. Habitats assessed were mangrove habitats in three zones (outer, middle and upper parts of the estuaries) within the five estuaries, seagrass beds in three of these estuaries, and to 17 habitats occurring in three zones in the Whangateau estuary. Insufficient information was available within the project timeframe to apply the tool to a wider range of habitats at different locations. However, the application of the tool was sufficient to test its effectiveness.

Although the contrast was not great, the zonal assessments of mangrove habitat indicated that, as expected, the Whangateau estuary was the least impacted environment and the Tamaki estuary was the most impacted ecosystem, but the three intermediate estuaries varied in their position on this gradient depending on the estuary zone being considered. A possible reason for the low contrast in the zonal assessments was the difficulty experienced by AC staff in dividing each estuary into zones which would allow meaningful comparisons within and among estuaries of differing size and complexity; without undue complication in the application of the MarHADS tool. Consideration should be given to the practicality of including a different classification system to better assist comparisons of habitats within and among estuaries. The Strahler stream order system may provide a superior approach and warrants further investigation.

In the seagrass assessments, although water quality, sediment quality, and biota were all highest for Whangateau estuary and lowest for Tamaki estuary other metrics were not as clear with the result that there was only a marginal difference in the total numbers of least impact scores among the estuaries assessed. This lack of contrast may be because of the differing location of the extant seagrass beds in the estuaries (in Tamaki and Mahurangi they were located in the outer zone

while in the Whangateau they were located in an upper zone). A broader assessment of seagrass habitats, including those in estuaries on Great Barrier Island, is probably required to identify the extremes of seagrass status within the Hauraki Gulf.

The application of the MarHADS tool to 17 benthic habitats within three zones in Whangateau estuary clearly indicated that intertidal sand flats were the least impacted habitat at this locality while mangroves were among the habitats worst affected by human activities. This result was not evident before the assessments had been undertaken and may stem from the position of mangroves around the estuary margins where they are accessible and more vulnerable to human activity. This accessibility and vulnerability of mangroves indicates they were a good choice for the initial comparison of the tool assessments among estuary systems.

The lack of any significant relationship between mean vulnerability score and mean certainty score for all active threats in mangrove forests across estuaries, and in habitats across zones in the Whangateau estuary, suggests that the assessment scores and the conclusions drawn from them were not significantly or consistently affected by the quality of the available information.

During a workshop with AC staff it was agreed that two methods should be used to combine scores across habitats within a defined sub-region. For most of the output assessment metrics, each score would be weighted by its proportional contribution to the total area of the sub-region, and all weighted scores then summed to calculate the sub-region score. For four metrics a simple count is required across assessments to identify the number of all active threats, 1º and 2º invasive species, and the number of endangered species. In these cases it would be inappropriate to weight the individual habitat scores by the proportional area of the habitat.

The combined assessment of mangrove habitat within each estuary as a whole provided a clear indication of a probable impact gradient in the western Hauraki Gulf with a regular decline in the total number of scores indicating a least impacted environment from Whangateau estuary (8) in the north to Tamaki estuary (4) in the south. Nine of the 14 metrics contributed towards this result, underscoring the usefulness of combining assessments within a locality when making comparisons among localities.

However, overall the metrics of mangrove habitat showed less contrast than may have been expected across the five estuaries. Although the assessments indicated that Whangateau estuary had the least impacted mangrove habitat, this habitat was nevertheless threatened by a considerable number of human activities and was not pristine. The mangrove habitat in Tamaki estuary, despite numerous threats and shown by the MarHADS tool to be in a poorer ecological state than Whangateau mangroves, was less degraded than might have been expected before the assessments were undertaken.

Score across 41 assessments of habitats in three zones (upper A and B and middle) in Whangateau estuary were combined to produce a single assessment for each habitat. This produced results that differed little from those for habitats in each zone of Whangateau estuary as there was little contrast in these assessments among zones, and nine habitats occurred in only a single zone. The major difference was that in some cases the number of human threats active in each habitat was higher than the individual zone totals as different threats sometimes occurred in different zones.

The assessments undertaken indicated the effectiveness of the different metrics in different situations. The number of active threats, the mean vulnerability score based on these active threats and the three ecosystem services provided contrast in all applications. Assessments of water quality, sediment quality, and biota provided little or no contrast within zones or estuaries but were effective at providing contrast among estuaries. The overall assessment of habitat quality provided little contrast across habitats, zones or estuaries. This metric should be re-examined to determine if more or different levels should be introduced, whether it should be applied differently, or dropped entirely. The number of invasive species present in a habitat provided no contrast within or among estuaries principally because at present this measure is based on regional scale information. The assessment of mean habitat vulnerability across all threats, even those that are not present in a habitat, zone or estuary, down-weights the contribution of active threats and was confusing to interpret. Consideration should be given to dropping this metric from the usual list of metrics reported from the tool.

For effective implementation the MarHADS tool requires a great deal of knowledge and information to be available about habitats at identified localities. The amount of information required is probably little different from that needed to effectively assess terrestrial or freshwater habitats; but in marine areas the lack of even basic habitat maps is so widespread that the needs of the MarHADS tool highlights this deficit. More effort is required to overcome this information deficit.

Our experience in this project indicates that familiarisation with the available information is a key to rapid application of the tool. While application of the tool by experienced and knowledgeable AC coastal scientists should be straightforward, a review of a subset of assessed habitats by other experienced staff should be standard practice to ensure consistent application.

Table of Contents

Executive Summary iv
Table of Contents vii
1 Introduction 1
1.1 Background 1
1.2 Project objectives 2
2 Methods and results 3
2.1 Kick-off workshop 3
2.2 Testing the tool on specific habitats 4
2.2.1 Assessment of mangrove habitat in estuary zones 11
2.2.2 Assessment of seagrass habitat 18
2.3 Applying the tool to all habitats within selected locations 19
2.4 Workshop to develop a method to combine habitat scores 26
2.5 Apply agreed methodology across all mangrove assessments for five estuaries 27
2.6 Apply agreed methodology across the habitat assessments completed for Whangateau estuary 29
3 Discussion and conclusions 32
4 Recommendations 36
5 Acknowledgements 38
6 References and bibliography 39
Appendix: Assessment of vulnerability worksheets 44

1 Introduction

1.1 Background

Regional councils have specific management responsibilities over coastal waters and habitats out to 12 nm offshore, New Zealand's territorial sea limits. In the face of increasing use of coastal resources Regional Councils must:

- Recognise and provide for the matters of national importance listed in Section 6 of the Resource Management Act (RMA), particularly the preservation of natural character (which includes an ecological element) (Section 6a) and protection of indigenous vegetation and fauna (Section 6c).
- Give effect to the policies on natural character in the New Zealand Coastal Policy Statement (NZCPS) (Department of Conservation 2010).
- Take into consideration the New Zealand Biodiversity Strategy (NZBS) (2000) to halt the decline in New Zealand's indigenous biodiversity, maintain and restore a full range of remaining natural habitats and ecosystems to a healthy functioning state, enhance critically scarce habitats, and sustain the more modified ecosystems in production and urban environments.
- Protect a full range of natural marine habitats and ecosystems to effectively conserve marine biodiversity.

Over the period 2008-2011 the Marine Habitat Assessment Decision Support (MarHADS) tool was jointly developed by NIWA and a team of regional council coastal scientists and planners to assist regional council resource managers and decision makers to critically assess the relative state and value of coastal habitats. It was envisaged by the participating councils that standardisation of the assessments through application of the tool would enable comparison of habitat values within and among regions and at a national level. The tool incorporates five types of knowledge about marine habitats. These are:

1. The quantity of habitat – the actual and relative size of the habitat in question on local, regional, bioregional and national scales.
2. Habitat vulnerability – this includes likely threats, their scale and functional impact, as well as the resilience of the habitat to those particular threats, the recovery timescale once the threat is removed and the level of uncertainty in assessments of these factors given the state of knowledge about them.
3. The nationally threatened and at risk species that may occur within particular habitats.
4. Habitat quality as assessed by the number of invasive species, water quality, sediment quality, the degree to which the expected biotic assemblage remains intact, and an overall assessment of the degree that expected ecosystem features and functions remain in operation.
5. The level of regulatory, provisioning, and non-consumptive ecosystem goods and services provided by marine habitats.

In the first use of this tool, it was recommended that regional councils assess examples of each habitat type within their region that lie at, or near, the extremes of environmental degradation and pristineness. Habitats occurring within long-established marine reserves could provide one extreme; local knowledge could suggest the locations of the other extreme. These initial assessments would then provide immediate knowledge of the likely range of environmental characteristics for each habitat that would indicate its regional significance. As further assessments were undertaken the proportions of a habitat within a region that lie along this gradient would become increasingly apparent. Regular sharing of habitat assessments among councils would help to indicate the likely range of environmental characteristics for each habitat that would indicate its national significance. However, to-date no council has used the MarHADS tool to assess any marine habitats.

1.2 Project objectives

Auckland Council (AC) contracted NIWA to undertake initial trials of the MarHADS tool in the AC region by applying it to areas of habitat that lie at either end of the range in habitat quality and human impacts (e.g. mangroves forest in the Whangateau and Tamaki estuaries). Once the tool was demonstrated to yield useful information, AC then required NIWA to apply the tool to all habitats within a selected sub-region (e.g. Whangateau estuary). There is presently no agreed method for summing the habitat scores separately assessed within a sub-region such as a harbour, estuary, or bay. AC requested that NIWA work with AC staff to devise an appropriate technique for habitat assessments within a sub-region to be combined.

The scope of the work as set out in contract ACPN_10824 signed on 20 March 2013 was as follows:

1. Workshop with the NIWA project team and AC team in Auckland to familiarise everyone with the tool and its information requirements, and identify where the relevant information is and how to access it.
2. Apply the tool to areas of habitat that are at the extremes of an impact gradient at locations reasonably well known and with good data sets so it can be demonstrated that the tool yields scores that make ecological sense.
3. Apply the tool to all the habitats within selected sub-regions where there is good habitat information.
4. Workshop with NIWA and AC teams in Auckland to agree on an approach to combine the individual habitat scores for a sub-region.
5. Apply agreed methodology across the assessments completed for a sub-region.
6. Deliver a report detailing the work undertaken and any conclusions that can be drawn.

2 Methods and results

2.1 Kick-off workshop

The NIWA team met with AC staff (Megan Carbines, Marcus Cameron, Jarrod Walker, and Melanie Vaughan) at the AC offices in Takapuna to familiarise everyone with the MarHADS tool and its data needs. The availability of the necessary information to apply the tool was discussed. It was clear that data availability was highly variable across the region with some localities and habitats well described and some relatively poorly known. For these reasons it was agreed to apply the tool to all or some of the following habitats, depending on time and available information:

1. Assess the state of mangrove forest habitat
   a). Assess selected forest stands within defined zones in the Tamaki, Whangateau, Mahurangi, Waiwera and Puhoi estuaries. These zones were defined by AC staff on the basis of the hydrological system in each estuary to help ensure that similar environments were compared across estuaries.
   b). Assess total mangrove habitat within each zone of the above estuaries.
   c). Assess all mangrove habitat within each east coast estuary of the AC region.
2. Assess total seagrass habitat within defined zones within Whangateau, Tamaki and Mahurangi estuaries, and if time allows and information is available, St Helier's Beach, Meola Reef, and Okoromai Bay (Whangaparoa).
3. Assess all habitats within Whangateau estuary (and potentially one other location if sufficient data are available).
4. If analysis of satellite imagery of intertidal and shallow subtidal reefs is completed in time, assess the state of east coast kelp or shallow mixed algae.

During the workshop it was agreed that:

- The assessment of vulnerability using the MarHADS tool would be based on current or imminent threats to the area of habitat being assessed. For other work it was agreed that AC could test scenarios to determine the impact of defined new threats, or determine general vulnerability of each habitat type to establish the different types of regional management required.
- As information about the distribution of endangered species is limited, the MarHADS assessments will use a precautionary approach to score them as present if there is good reason to believe habitat type and condition means endangered species might be present.

2.2 Testing the tool on specific habitats

Once access to survey and environmental monitoring data was established the tool was used to assess mangrove forests and seagrass beds across five estuaries (Figure 2-1, Figure 2-2) that ranged in size from the Mahurangi estuary with a total area of 25.2 km^2 to the Waiwera estuary with a total area of 1.2 km^2 (AC ArcGIS). These estuaries were chosen for assessment as it was widely understood they lay on an impact gradient with the Whangateau estuary in the north having the most pristine environment and the Tamaki estuary in the heart of Auckland City being the most heavily impacted by human activities.

The MarHADS tool was also used to assess all habitats in the Whangateau estuary for which a detailed habitat map was available (Figure 2-4, Figure 2-5). Note that the configuration of zones in the Whangateau Estuary was defined differently to the other estuaries with two upper zones and a middle but no outer zone. The intersect tool in ArcGIS was used to calculate the total areas of habitat type within each estuary zone. The intertidal vegetation shapefile was intersected with the estuary zone shapefile. The resultant polygons were then summarised based on area of vegetation type falling within each zone. Habitats in each zone were assessed separately following the procedures specified in MacDiarmid et al. (2011).

A wide range of information was searched for and used to undertake the habitat assessments. Much of this information was obtained via published and unpublished papers and reports (see Section 6: Bibliography). We also used an AC ArcGIS and where necessary Google Earth to obtain images and maps of each habitat to define vehicle access and the location and extent of coastal engineering such as seawalls, bridge approaches, causeways, pipelines, wharfs, pilings, boat marinas, boat ramps, etc.

Preliminary assessments were carried out by NIWA and then a proportion of these were reviewed by AC staff who had personal knowledge of the habitats and used AC ArcGIS to check the location of facilities from the available information layers (Table 2-1). Knowledge gained through this review process was then applied across all assessments (see assessment notes in Appendix A).

Table 1: Estuaries and habitats in the Auckland region that have been assessed using the MarHADS tool

Assessments reviewed by AC staff are indicated

Estuary	Habitat	Zone	Assessment reviewed by AC
Whangateau	Saltmarsh	Upper A	-
Whangateau	Saltmarsh	Upper B	-
Whangateau	Saltmarsh	Middle	-
Whangateau	Beach -shelly	Upper A	-
Whangateau	Beach -shelly	Upper B	-
Whangateau	Beach -shelly	Middle	-

Estuary	Habitat	Zone	Assessment reviewed by AC
Whangateau	Mangrove forest	Upper A	Assessment reviewed by AC
Whangateau	Mangrove forest	Upper B	Assessment reviewed by AC
Whangateau	Mangrove forest	Middle	Assessment reviewed by AC
Whangateau	Intertidal sands	Upper A	-
Whangateau	Intertidal sands	Upper B	-
Whangateau	Intertidal sands	Middle	-
Whangateau	Rubble on sand	Upper B	-
Whangateau	Reef	Upper A	-
Whangateau	Reef	Upper B	-
Whangateau	Reef	Middle	-
Whangateau	Hard packed sand	Upper A	-
Whangateau	Hard packed sand	Upper B	-
Whangateau	Hard packed sand	Middle	-
Whangateau	Sand bank	Upper B	-
Whangateau	Seagrass	Upper A	Assessment reviewed by AC
Whangateau	Channel - minor	Upper A	-
Whangateau	Channel - minor	Upper B	-
Whangateau	Channel - minor	Middle	-
Whangateau	Cockle shell	Middle	-
Whangateau	Reef with Sand	Middle	-
Whangateau	Shelly Sand	Middle	-
Whangateau	Subtidal Sand	Middle	-
Whangateau	Subtidal sand & shell	Middle	-
Whangateau	Subtidal Shell	Middle	-
Whangateau	Weed on rock	Middle	-
Mahurangi	Mangrove forest	Upper	Assessment reviewed by AC
Mahurangi	Mangrove forest	Middle	Assessment reviewed by AC
Mahurangi	Mangrove forest	Outer	Assessment reviewed by AC
Puhoi	Mangrove forest	Upper	Assessment reviewed by AC
Puhoi	Mangrove forest	Middle	Assessment reviewed by AC
Puhoi	Mangrove forest	Outer	Assessment reviewed by AC
Waiwera	Mangrove forest	Upper	-
Waiwera	Mangrove forest	Middle	-
Waiwera	Mangrove forest	Outer	-
Tamaki	Mangrove forest	Upper	Assessment reviewed by AC
Tamaki	Mangrove forest	Middle	Assessment reviewed by AC
Tamaki	Mangrove forest	Outer	Assessment reviewed by AC
Tamaki	Intertidal sands	Upper	-
Tamaki	Intertidal sands	Middle	-
Tamaki	Intertidal sands	Outer	-

Figure 1: Distribution of mangrove, saltmarsh and seagrass habitats in estuaries along the western fringe of the Hauraki Gulf

(AC map derived from: Auckland Council, DoC, Landcare Research, LINZ, NIWA, Swales 2009). The four framed areas are shown in more detail in figure 2.

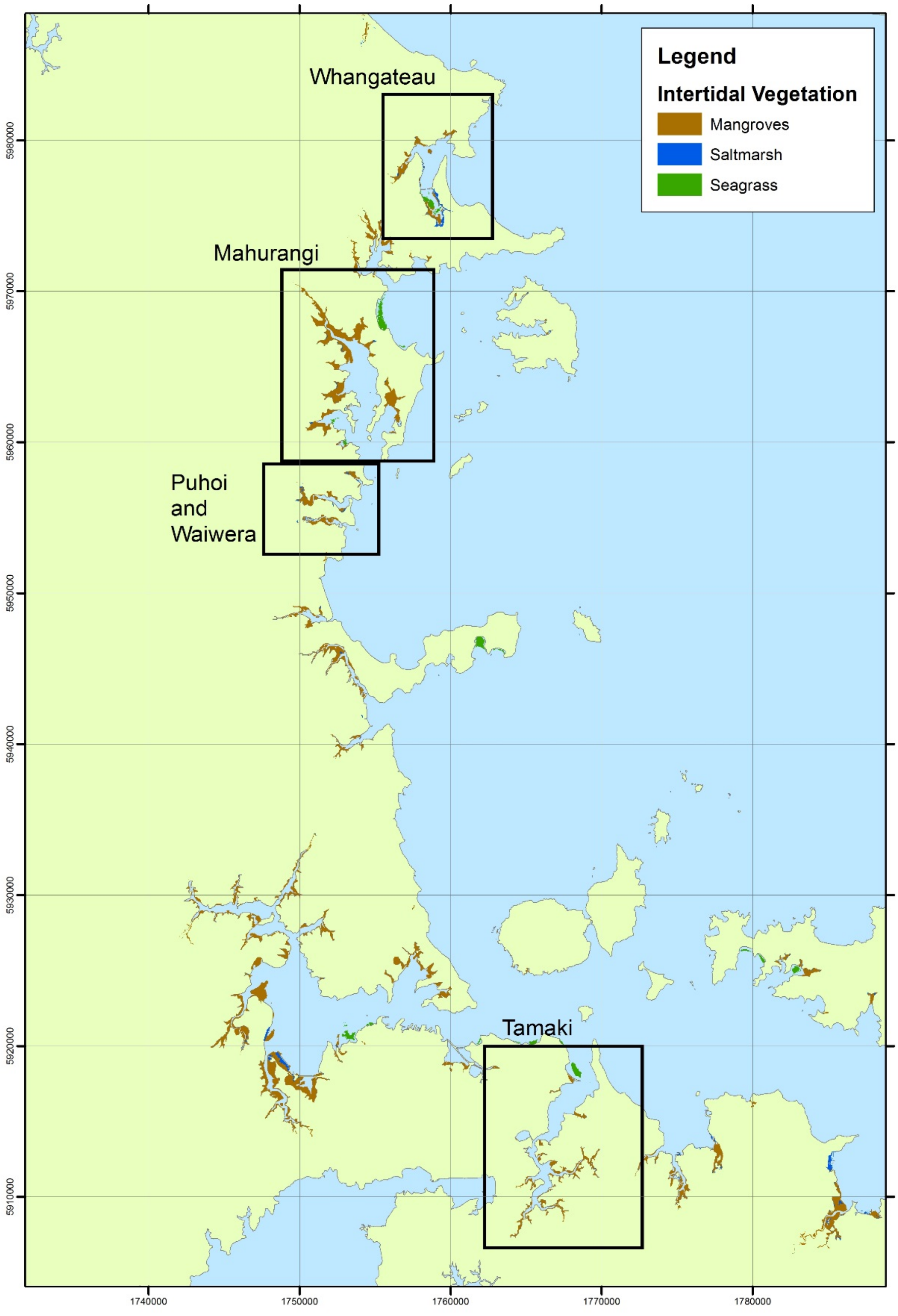


Figure 2: Distribution of mangrove forest, saltmarsh and seagrass habitats in Whangateau (A), Mahurangi (B), Puhoi, Waiwera (C) and Tamaki (D) estuaries.

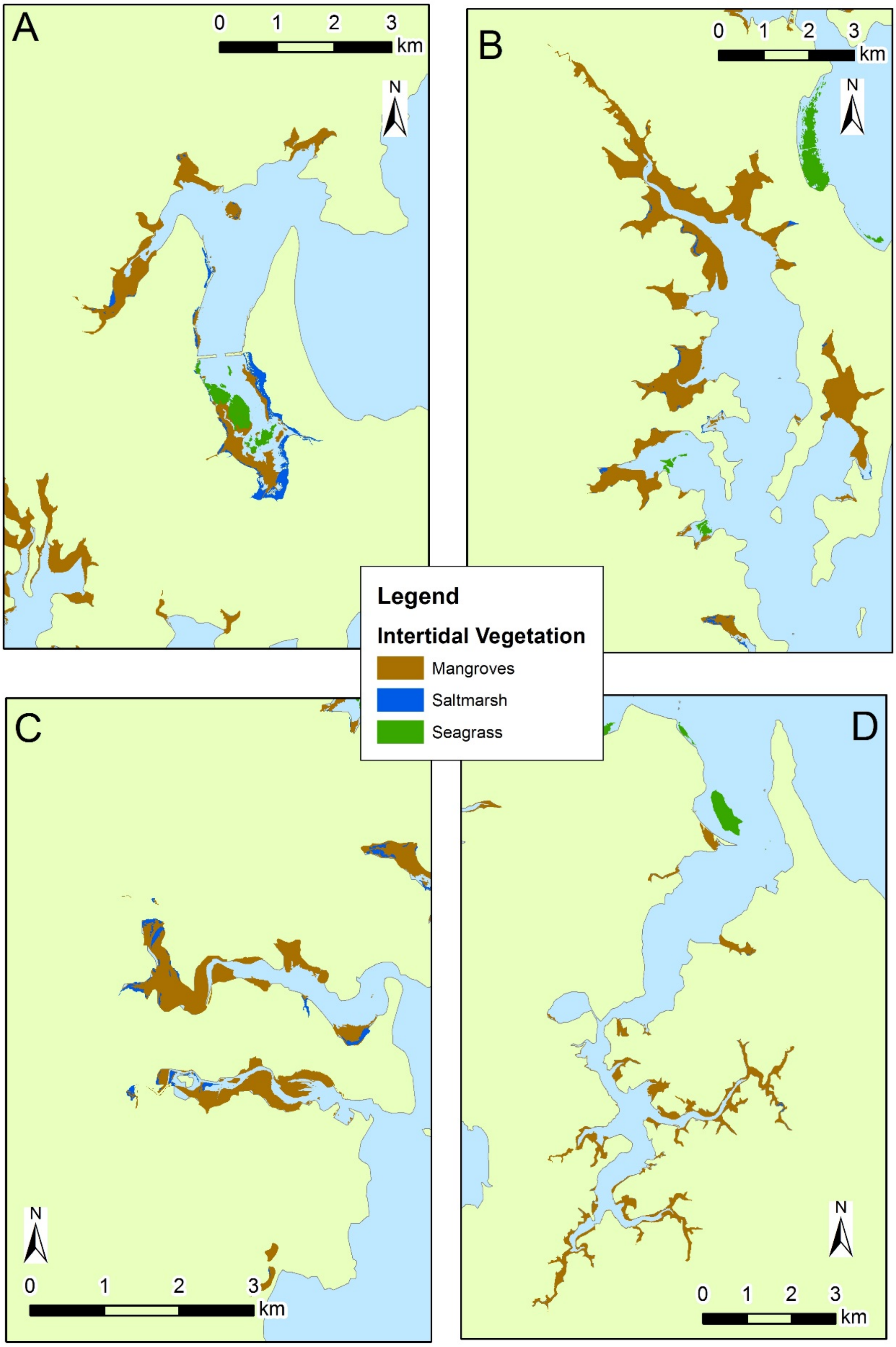


Figure 3: Subtidal and intertidal habitats assessed in the Whangateau estuary. From Townsend et al. (2010).

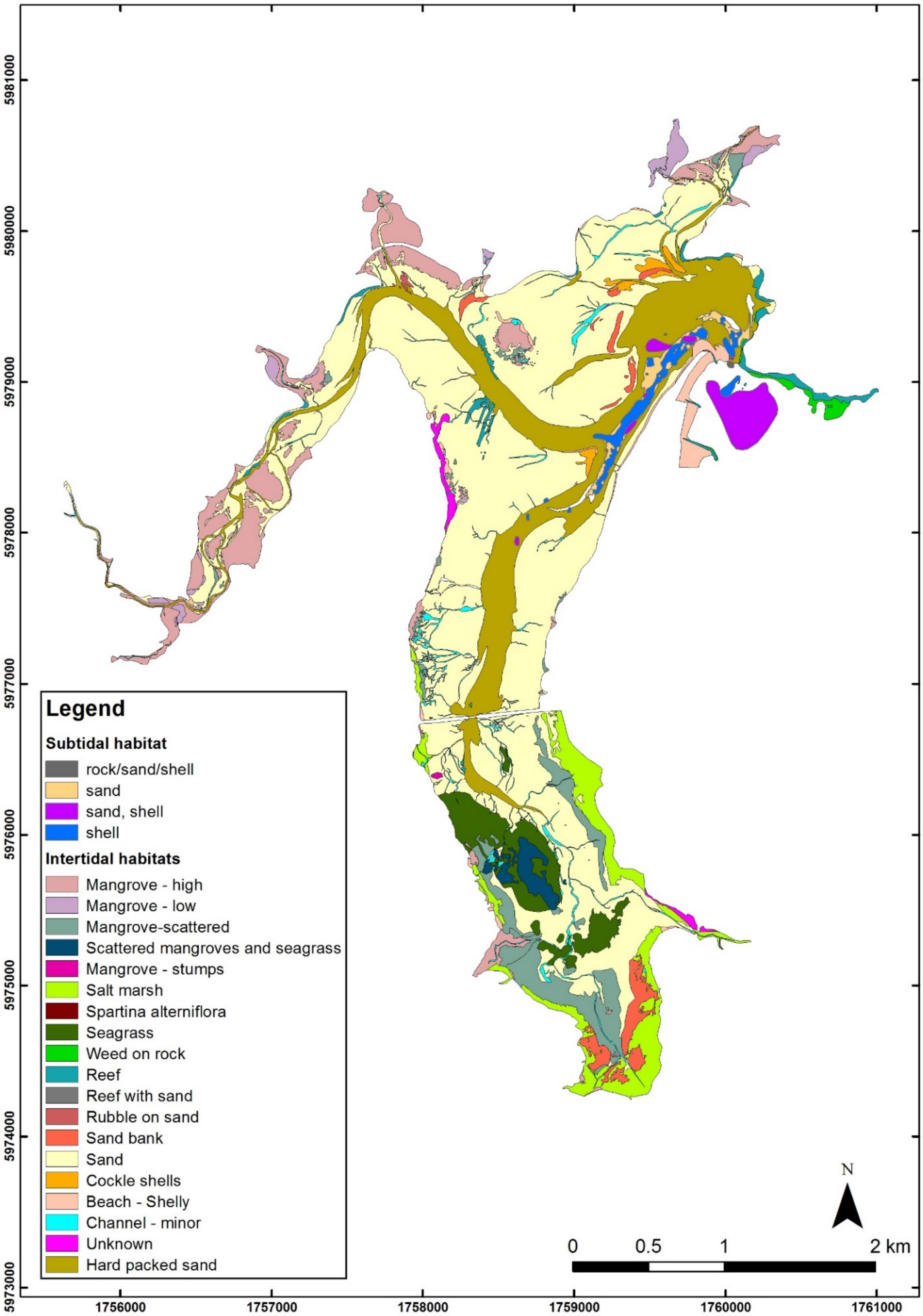


Figure 4: Upper, middle and outer zones of five estuaries along the western fringe of the Hauraki Gulf. From north to south, these are Whangateau, Mahurangi, Puhoi, Waiwera and Tamaki estuaries. The four framed areas are shown in more detail in Figure 5 below.

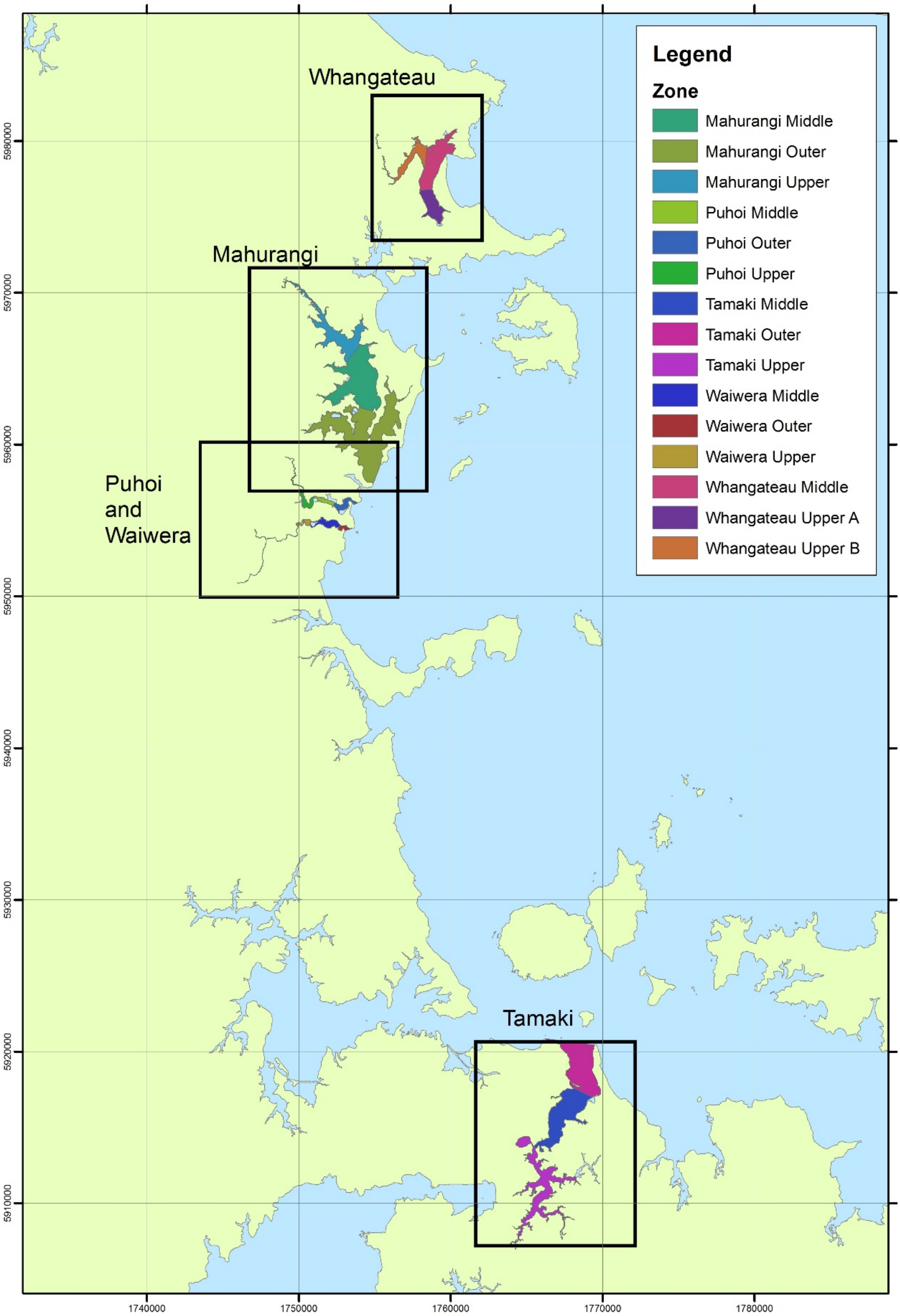
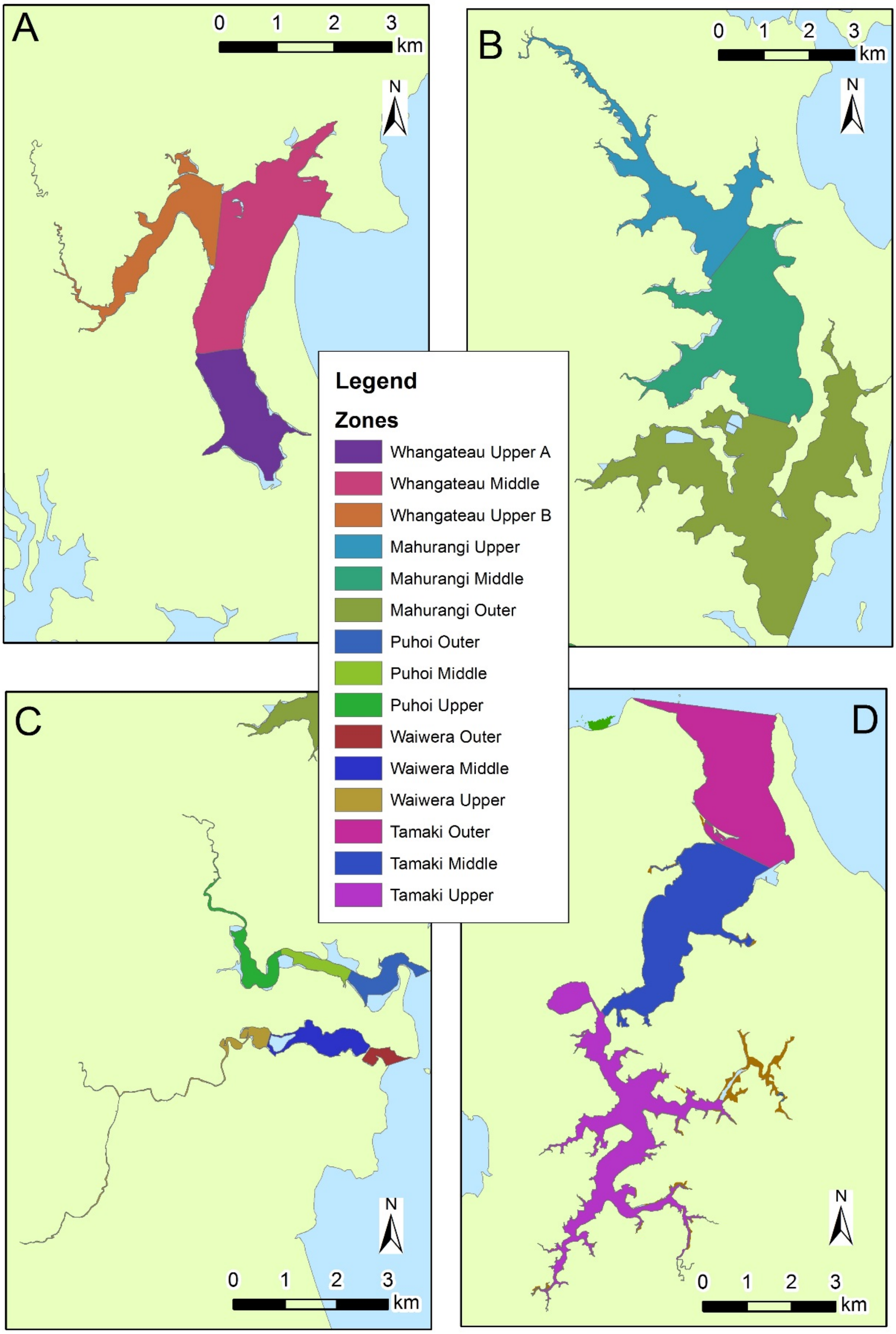


**Figure 5: Designated zones in the Whangateau (A), Mahurangi (B), Puhoi, Waiwera (C) and Tamaki (D)
estuaries.**



2.2.1 Assessment of mangrove habitat in estuary zones

Mangrove forest comprised between 7.6% and 33.3% of the total area of each estuary assessed (see Figure 2-2) and between 0.5% and 8.8% of the regional total area of this habitat (Table 2-2).

Table 2: Total estuary areas

Total estuary areas, areas of mangroves, the percentage of the total estuary areas comprising mangrove habitat, and the percentage of the regional total area of mangrove habitat in Whangateau, Mahurangi, Puhoi, Waiwera and Tamaki estuaries in the Auckland Region. Note in this and the following tables the estuaries are listed from northernmost to southernmost. The total areas of the estuaries and areas of mangrove forest were calculated from data received from AC on the 28th May 2013. The per cent of regional total area of mangrove habitat was derived from data stored in the MarHADS tool.

Estuary	Total area (km^2)	Mangrove forest (km^2)	% mangrove habitat	% of regional mangrove habitat
Whangateau	7.5	1.1	14.7	1.9
Mahurangi	25.2	5.3	21.0	8.8
Puhoi	1.4	0.3	21.4	0.5
Waiwera	1.2	0.4	33.3	0.6
Tamaki	17.0	1.3	7.6	2.2

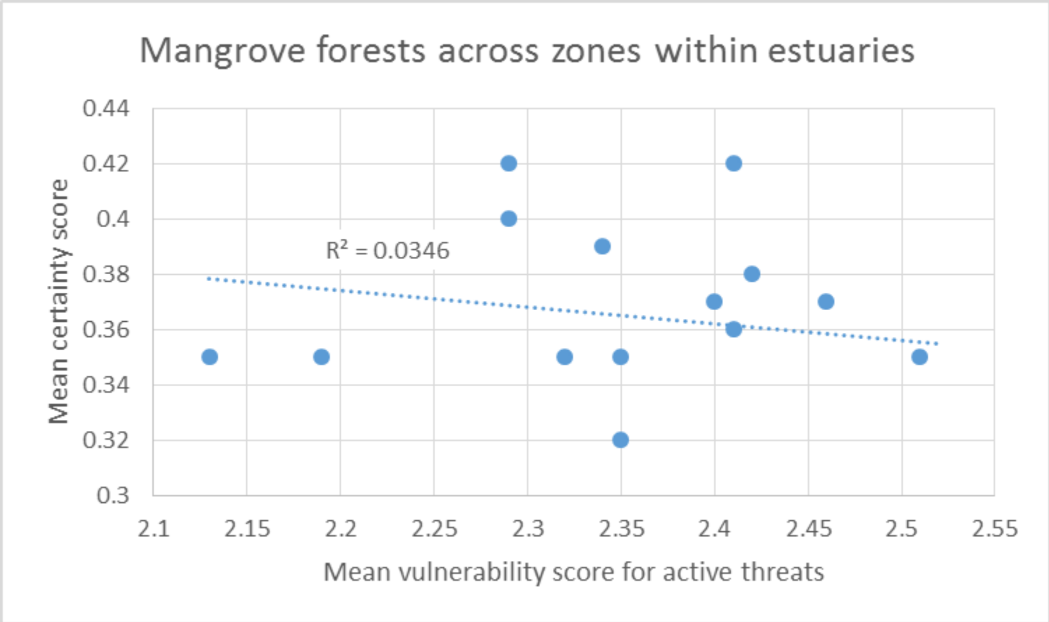
Assessments of mangrove habitat in the upper, middle and outer zones of the five estuaries using 14 metrics generated by the MarHADS tool are shown in Table 2-3, Table 2-4, and Table 2-5, respectively. Note that because the configuration of the zones in Whangateau Estuary is different to the other estuaries, we used its upper A zone for comparison with upper zones from other estuaries, the upper B zone for comparison with middle zones from other estuaries, and the middle zone (outermost) for comparison with outer zones from other estuaries.

The number of active threats varied from 28 to 34 in the Upper zone, 30 to 35 in the middle zone, and 29 to 35 in the outer zone. However, the highest and lowest number of threats was not consistent between estuaries. In the upper zone, Waiwera estuary had the lowest number of active threats whereas Whangateau and Tamaki estuaries had the most. In the middle zone, Puhoi estuary had the least number of active threats, Mahurangi and Tamaki estuaries the most. In the outer zone, Tamaki estuary had the least number of active threats and Mahurangi estuary the most.

Vulnerability scores within the MarHADs tool can range from 0 to a high of 4. The mean vulnerability score of mangrove habitat in the upper zone over all threats, including inactive threats listed in the tool, ranged from 0.95 in the Puhoi and Waiwera estuaries to 1.17 in the Tamaki estuary. In the middle zone scores ranged from 0.93 in the Puhoi estuary to 1.16 in the Tamaki estuary. In the outer zone scores ranged from 0.99 in the Waiwera estuary to 1.19 in the Mahurangi. As vulnerability scores in the MarHADS tool can range from 0 to a high of 4 the range of mean scores suggests a low impact of human activities. However, this particular metric averages scores across all activities listed by the tool, including those not occurring in this habitat so the scores of important threats are down-weighted.

A better reflection of the magnitude of human activities affecting mangrove forests is the mean vulnerability score of active threats, i.e. those actually occurring in the habitat. This metric ranged from 2.32 to 2.51 in the upper zone, 2.19 to 2.41 in the middle zone, and 2.13 to 2.52 in the outer zone, with Whangateau estuary the least impacted and Tamaki estuary most impacted in each zone (Table 2-3, Table 2-4, Table 2-5). This range of scores indicates the mangrove forests assessed were on average moderately affected by human activities. The vulnerability assessments were only weakly affected by the quality of the information available to assess the mangrove habitats (R^2 = 0.035), with the highest mean vulnerability scores having marginally lower certainty (Figure 2-6).

Figure 6: Relationship between mean vulnerability score and mean certainty score for all active threats in zones in five estuaries in the AC region. The liner relationship and R^2 value are shown.



The assessment of water quality and sediment quality in mangrove forests indicated these covaried with the highest scores for both in Whangateau estuary, which generally had excellent water quality and good quality sediments (Table 2 3, Table 2 4, Table 2 5). Tamaki estuary scored the lowest for both water and sediment quality, particularly the upper and middle zones, but the scores indicated only moderate impacts on the quality of these important ecosystem indicators.

The metrics for three types of ecosystem services showed some contrast across mangrove forests in the five estuaries (Table 2 3, Table 2 4, Table 2 5). Regulatory services scored higher than other services and were consistently highest for mangrove forest in all three zones of Mahurangi estuary, but the lowest score varied among other estuaries dependent on zone. Provisioning services generally scored lower than other ecosystem services in all zones in all estuaries with either Mahurangi estuary or Waiwera estuary scoring the highest and Tamaki estuary always the lowest. Non-consumptive ecosystem services scored at intermediate levels compared to the other two services with Whangateau estuary consistently providing the highest level of service and Tamaki estuary the lowest. The numbers of endangered or threatened species showed no variation among zones within an estuary. In contrast to the other metrics, mangroves in Tamaki estuary consistently had the highest number of nationally threatened species present. Three metrics provided very little or no contrast; the number of 1° and 2° invasive species and overall habitat quality had the same score across all estuaries.

Across all metrics provided in Table 2-3, Table 2-4, and Table 2-5, mangroves in Whangateau estuary had the highest total number of scores indicating the least impacted environment (24 across the three zones) whereas Tamaki estuary had the lowest total (14 across the three zones). There was generally a small amount of variation in assessments of mangroves among zones within an estuary.

Table 3: Assessment of upper zone mangrove habitat in five estuaries using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted locality are highlighted for each metric. Note for Whangateau estuary this assessment is for Upper A.

Assessment metric	Whangateau	Mahurangi	Puhoi	Waiwera	Tamaki
Total number of threats active in this habitat	34	31	29	28	34
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	1.08	1.02	0.95	0.95	1.17
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.32	2.41	2.40	2.46	2.51
Mean certainty for threats active in this habitat (range 0-1 high)	0.35	0.42	0.37	0.37	0.35
Number of 1° invasive species	0	0	0	0	0
Number of 2° invasive species	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	3.00
Sediment quality, mean score (range 0-4 high)	3.75	3.33	3.66	3.66	2.5
Biota, mean score (range 0-4 high)	3	2	2	2	2
Habitat quality, mean score (range 0-4 high)	3	3	3	3	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	2.50	3.50	3.17	3.25	3.33
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.50	0.67	0.50	0.83	0.50
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.56	1.89	2.33	2.33	1.67
Number of endangered species in habitat	5	0	2	2	10
Total number of least impact scores	*8*	*6*	*5*	*7*	*4*

Table 4: Assessment of middle zone mangrove habitat in five estuaries using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted locality are highlighted for each metric. Note for Whangateau estuary this assessment is for Upper B

Assessment metric	Whangateau	Mahurangi	Puhoi	Waiwera	Tamaki
Total number of threats active in this habitat	34	35	29	33	35
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	1.02	1.10	0.93	1.06	1.16
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.19	2.29	2.35	2.35	2.41
Mean certainty for threats active in this habitat (range 0-1)	0.35	0.42	0.32	0.35	0.36
Number of 1° invasive species	0	0	0	0	0
Number of 2° invasive species	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	3.00
Sediment quality, mean score (range 0-4 high)	3.75	3.5	3.66	3.66	2.5
Biota, mean score (range 0-4 high)	3	2	2	2	2
Habitat quality, mean score (range 0-4 high)	3	3	3	3	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	3.08	3.50	2.58	3.25	3.17
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.67	1.50	0.50	0.83	0.50
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.78	1.89	2.33	2.33	1.63
Number of endangered species in habitat	5	0	2	2	10
Total number of least impact scores	*8*	*7*	*6*	*4*	*5*

Table 5: Assessment of outer zone mangrove habitat in five estuaries using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted locality are highlighted for each metric. Note for Whangateau estuary this assessment used the outer-most zone (Middle)

Assessment metric	Whangateau	Mahurangi	Puhoi	Waiwera	Tamaki
Total number of threats active in this habitat	35	38	31	30	29
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	1.02	1.19	1.00	0.99	1.00
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.13	2.29	2.34	2.42	2.52
Mean certainty for threats active in this habitat (range 0-1)	0.35	0.40	0.39	0.38	0.29
Number of 1° invasive species	0	0	0	0	0
Number of 2° invasive species	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	3.57
Sediment quality, mean score (range 0-4 high)	3.75	3.33	3.75	3.66	3
Biota, mean score (range 0-4 high)	3	2	2	2	2
Habitat quality, mean score (range 0-4 high)	3	3	3	3	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	2.33	3.50	2.42	2.17	3.17
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.50	1.17	0.50	0.50	0.50
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.44	2.44	2.33	2.33	1.63
Number of endangered species in habitat	5	0	2	2	10
Total number of least impact scores	*8*	*8*	*5*	*5*	*5*

2.2.2 Assessment of seagrass habitat

Seagrass beds were present in only three of the five localities investigated (Whangateau, Mahurangi and Tamaki estuaries), where they comprised between 0.5% and 3.9% of the total estuary area and less than 1% of the regional total of seagrass beds (Table 2-6).

Table 6: Total estuary areas, areas of seagrass beds, the percentage of the total area comprising seagrass habitat, and the percentage of the regional total area of seagrass habitat

Whangateau, Mahurangi, Puhoi, Waiwera and Tamaki estuaries in the Auckland Region. (-) indicates not present. The total areas of the estuaries and areas of seagrass were calculated from data received from AC on the 28th May 2013. The per cent of the regional total area of seagrass habitat was derived from data stored in the MarHADS tool.

Estuary	Total area km^2	Seagrass beds km^2	% seagrass habitat	% of regional seagrass habitat
Whangateau	7.5	0.4	5.3	0.8
Mahurangi	25.2	0.1	0.4	0.3
Puhoi	1.4	-	-	-
Waiwera	1.2	-	-	-
Tamaki	17.0	0.4	2.4	0.8

Assessments of seagrass habitat at these localities using 14 metrics generated by the MarHADS tool are shown in Table 2-7. Scores indicating the least impacted locality are highlighted for each metric. The total number of active threats in seagrass beds was the least in Tamaki estuary as was the mean vulnerability score across all threats listed by the MarHADS tool. The mean vulnerability score for only those threats actually affecting seagrass beds was the least for Mahurangi estuary, but the poorest-scoring bed in Tamaki estuary had only a marginally higher mean score. Assessments of water quality, sediment quality, and biota were all highest for Whangateau estuary and lowest for Tamaki estuary. The magnitude of the three categories of ecosystem services indicated that seagrass beds in Mahurangi estuary consistently provided the greatest level of service compared to seagrass beds in the other estuaries evaluated. Seagrass beds in Tamaki estuary had the largest number of nationally threatened species present. There was no contrast in seagrass beds across estuaries for three metrics: numbers of 1^o and 2^o invasive species, or the overall assessment of habitat quality. Across all 14 metrics listed in Table 2-7, seagrass beds in Mahurangi estuary scored marginally better than those in Whangateau and Tamaki estuaries.

Table 7: Assessment of seagrass habitat using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted locality are highlighted for each metric

Assessment metric	Upper A Whangateau	Outer Mahurangi	Puhoi	Waiwera	Outer Tamaki
Total number of threats active in this habitat	28	31	-	-	26
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.93	1.03	-	-	0.91
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.44	2.43	-	-	2.57
Mean certainty for threats active in this habitat (range 0-1)	0.38	0.36	-	-	0.32
Number of 1° invasive species	0	0	-	-	0
Number of 2° invasive species	1	1	-	-	1
Water quality, mean score (range 0-4 high)	4.00	4.00	-	-	3.71
Sediment quality, mean score (range 0-4 high)	3.75	3.33	-	-	3
Biota, mean score (range 0-4 high)	3	2	-	-	2
Habitat quality, mean score (range 0-4 high)	3	3	-	-	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	3.08	3.50	-	-	3.08
Ecosystem G & S, Provisioning mean score (range 0-4 high)	1.00	1.17	-	-	1.17
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.11	2.22	-	-	1.63
Number of endangered species in habitat	3	0	-	-	10
Total number of least impact scores	*7*	*8*	-	-	*7*

2.3 Applying the tool to all habitats within selected locations

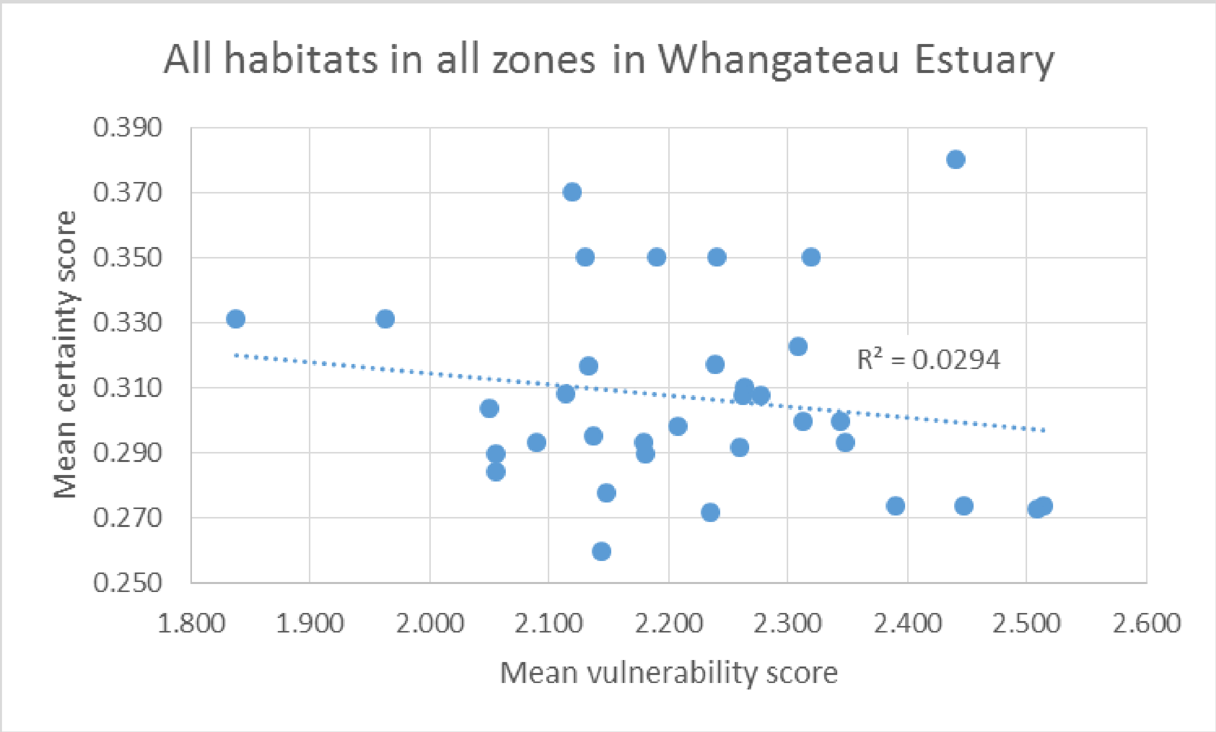
The tool was used to assess all 17 habitats within Whangateau estuary for which maps of all habitats were readily available. The assessments for all habitats within the upper A, upper B, and middle zones of Whangateau estuary are shown in Table 2-8, Table 2-9, and Table 2-10 respectively. Note that not all habitats occurred in each zone and that some of the habitats shown in Figure 2-3 have been combined. For example, all the mangrove habitats (high, low, scattered) have been assessed as mangroves. Scores indicating the least impacted habitat are highlighted for each metric in each zone.

The total number of active threats in each zone ranged from 21 to 37 among nine habitats in the upper A zone, from 20 to 34 among nine habitats in the upper B zone, and from 22 to 37 among 15 habitats in the outer most (middle) zone.

The mean vulnerability score for each habitat over all threats in the upper A zone, including inactive threats, ranged from 0.70 in saltmarsh to 1.08 in mangrove forests. In the upper B zone scores ranged from 0.60 in the rubble-on-sand habitat to 1.02 in mangrove forests. In the outer most (middle) zone scores ranged from 0.64 on shelly sand to 1.02 in mangrove forest. As vulnerability scores in the MarHADS tool can range from 0 to a high of 4 the range of mean scores suggests a low impact of human activities. However, this particular metric averages scores across all activities listed by the tool, including those not occurring in this habitat so the scores of important threats are down-weighted.

A better reflection of the magnitude of human activities affecting habitats in each zone of Whangateau estuary was the mean vulnerability score of active threats, i.e. those actually occurring in the habitat. This metric ranged from 1.96 to 2.51 across habitats in the upper A zone, 2.06 to 2.45 in the upper B zone, and 1.84 to 2.51 in the outer most (middle) zone (Table 2-8, Table 2-9, Table 2-10). This range of scores indicates that habitats in all zones were on average moderately affected by human activities. The vulnerability assessments were only weakly affected by the quality of the information available to assess the different habitats (R^2 = 0.029), with the highest mean vulnerability scores having marginally lower certainty (Figure 2-7).

Figure 7: Relationship between mean vulnerability score and mean certainty score for all active threats in zones in the Whangateau estuary. The linear relationship and R^2 value are shown.



The metrics for three types of ecosystem services showed some contrast across habitats within zones in Whangateau estuary (Table 2-8, Table 2-9, Table 2-10). Regulatory services scored higher than other services in most habitats while provisioning services generally scored the lowest. Non-consumptive ecosystem services scored at intermediate levels compared to the other two services. In each zone, intertidal sands scored the highest level of production for each of the three types of ecosystem service.

The numbers of nationally endangered or threatened species occurring in a habitat showed little or no variation among zones but among habitats this metric ranged from zero in minor channels to six in intertidal sands.

Several metrics provided very little or no contrast among habitats within zones; the number of 1^{o} invasive species, and the assessments of water quality, sediment quality, biota and overall habitat quality had the same score across habitats within zones.

Across all metrics provided in Table 2-8, Table 2-9, and Table 2-10 intertidal sand was clearly the least impacted habitat as indicated by eight, nine, or ten of the metrics in the three zones.

Table 8: Assessment of habitats present in the upper A zone of Whangateau estuary using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted habitat within the zone are highlighted for each metric

Assessment metric	Saltmarsh	Beach-shelly	Mangrove	Intertidal sand	Reef	Hard packed sand	Sand bank	Seagrass	Minor channel
Total number of threats active in this habitat	23	21	34	37	26	30	27	28	25
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.70	0.72	1.08	0.99	0.81	0.88	0.79	0.93	0.79
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.23	2.51	2.32	1.96	2.28	2.13	2.15	2.44	2.31
Mean certainty for threats active in this habitat (range 0-1)	0.27	0.27	0.35	0.33	0.31	0.32	0.28	0.38	0.30
Number of 1° invasive species	0	0	0	0	0	0	0	0	0
Number of 2° invasive species	1	0	1	1	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Sediment quality, mean score (range 0-4 high)	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
Biota, mean score (range 0-4 high)	3	3	3	3	3	3	3	3	3
Habitat quality, mean score (range 0-4 high)	3	3	3	3	3	3	3	3	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	3.17	1.25	2.50	3.33	1.33	1.92	2.00	3.08	1.08
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.67	0.67	0.50	1.17	0.83	0.67	0.83	1.00	0.33
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.11	1.11	2.56	2.67	1.67	1.11	1.89	2.11	0.56
Number of endangered species in habitat	2	4	5	6	3	0	4	3	0
Total number of least impact scores	*5*	*6*	*4*	*9*	*4*	*5*	*4*	*6*	*4*

Table 9: Assessment of habitats present in the upper B zone of Whangateau estuary using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted habitat within the zone are highlighted for each metric

Assessment metric	Saltmarsh	Beach-shelly	Mangrove	Intertidal sand	Rubble on sand	Reef	Hard packed sand	Sand bank	Minor channel
Total number of threats active in this habitat	21	21	34	30	20	23	24	25	25
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.69	0.70	1.02	0.93	0.60	0.74	0.76	0.70	0.78
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.39	2.45	2.19	2.26	2.18	2.35	2.31	2.06	2.26
Mean certainty for threats active in this habitat (range 0-1)	0.27	0.27	0.35	0.29	0.29	0.29	0.32	0.29	0.31
Number of 1° invasive species	0	0	0	0	0	0	0	0	0
Number of 2° invasive species	1	0	1	1	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Sediment quality, mean score (range 0-4 high)	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
Biota, mean score (range 0-4 high)	3	3	3	3	3	3	3	3	3
Habitat quality, mean score (range 0-4 high)	3	3	3	3	3	3	3	3	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	2.75	1.25	3.08	3.25	1.75	1.00	1.92	2.00	1.67
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.33	0.67	0.67	1.00	0.33	0.50	0.67	0.83	0.67
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	1.78	1.44	2.44	2.89	0.56	1.33	1.33	1.89	0.89
Number of endangered species in habitat	2	4	5	5	5	3	0	5	0
Total number of least impact scores	*5*	*6*	*5*	*8*	*7*	*4*	*4*	*6*	*4*

Table 10: Assessment of habitats present in the middle zone of Whangateau estuary using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted habitat within the zone are highlighted for each metric. Note this table continues on the page below

Assessment metric	Saltmarsh	Beach-shelly	Mangrove	Intertidal sand	Reef	Hard packed sand	Sand bank	Minor channel	Cockle shell	Reef with Sand
Total number of threats active in this habitat	25	22	35	37	29	30	25	26	25	26
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.73	0.76	1.02	0.93	0.87	0.87	0.73	0.80	0.80	0.80
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.14	2.51	2.13	1.84	2.18	2.11	2.12	2.24	2.34	2.26
Mean certainty for threats active in this habitat (range 0-1)	0.26	0.27	0.35	0.33	0.29	0.31	0.37	0.32	0.30	0.31
Number of 1° invasive species	0	0	0	0	0	0	0	0	0	0
Number of 2° invasive species	1	0	1	1	1	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Sediment quality, mean score (range 0-4 high)	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Biota, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Habitat quality, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Ecosystem G & S, Regulatory mean score (range 0-4 high)	2.75	1.42	2.33	3.33	1.33	1.92	2.17	1.58	2.50	1.250
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.33	0.83	0.50	1.17	0.83	0.67	0.83	0.33	1.00	0.833
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	1.67	1.78	2.22	2.67	1.67	1.11	1.89	1.11	2.444	1.444
Number of endangered species in habitat	2	4	5	6	3	0	4	0	4	3
Total number of least impact scores	*5*	*7*	*5*	*10*	*5*	*5*	*6*	*5*	*5*	*5*

Table 10: continued

Assessment metric	Shelly Sand	Subtidal Sand	Subtidal sand & shell	Subtidal shell	Weed on rock
Total number of threats active in this habitat	22	28	29	29	26
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.64	0.79	0.82	0.83	0.79
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.14	2.05	2.05	2.09	2.21
Mean certainty for threats active in this habitat (range 0-1)	0.29	0.30	0.28	0.29	0.30
Number of 1° invasive species	0	0	0	0	0
Number of 2° invasive species	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	4.00
Sediment quality, mean score (range 0-4 high)	3.67	3.67	3.67	3.67	3.67
Biota, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00
Habitat quality, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00
Ecosystem G & S, Regulatory mean score (range 0-4 high)	1.50	1.75	1.75	1.75	1.58
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.67	0.67	0.67	0.67	0.33
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	0.89	1.44	1.44	1.44	1.22
Number of endangered species in habitat	0	0	0	0	0
Total number of least impact scores	*7*	*5*	*5*	*5*	*5*

2.4 Workshop to develop a method to combine habitat scores

A second workshop with NIWA team members and AC staff was held in Auckland at the AC offices in Manukau on 27 May 2013. The main aim of the workshop was to agree on an approach to combining scores across habitats within a defined sub-region. After some discussion of what the combined metrics should reflect it was agreed that two methods should apply. For most of the assessment metrics, each score would be weighted by its proportional contribution to the total area of the sub-region, and all weighted scores then summed to calculate the sub-region score (Table 2 11). This can be easily calculated by applying a simple formula in an Excel worksheet. For example, to combine the mean vulnerability score for active threats across a sub-region of a harbour comprising just two habitats, mangrove and mud the Excel formula would have the following form:

=(mangrove score * proportional area of mangrove) + (mud score * proportional area of mud) (1)

However, for four of the metrics a count is required to identify the number of all active threats, 1^{o} and 2^{o} invasive species, and the number of endangered species. In these cases, it would be inappropriate to weight the individual habitat scores by the proportional area of the habitat.

Table 11: Method to combine scores across assessments for each MarHADS metric

Assessment metric	Combined score
Total number of threats active in this habitat	Count of all active threats
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Mean vulnerability score for threats active in this habitat (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Mean certainty for threats active in this habitat (range 0-1)	Sum of scores each weighted by proportional area of total sub-region area
Number of 1° invasive species	Count of all 1^{o} invasive species
Number of 2° invasive species	Count of all 2^{o} invasive species
Water quality, mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Sediment quality, mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Biota, mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Habitat quality, mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Ecosystem G & S, Regulatory mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Ecosystem G & S, Provisioning mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	Sum of scores each weighted by proportional area of total sub-region area
Number of endangered species in habitat	Count of all endangered species

2.5 Apply agreed methodology across all mangrove assessments for five estuaries

We applied the agreed methodology across assessments of mangrove habitat in three zones to produce a single combined assessment for mangrove habitat in each estuary (Table 2-12). This combined assessment takes into account the relative areas of mangrove habitat in each zone. However, in most respects the results differ little from those presented earlier for mangroves in each zone in each estuary (Section 2.2.1) as there was little contrast in these assessments among zones. The major difference is that the number of human threats active in mangrove habitat in each estuary is higher than the individual zone totals as different threats sometimes occurred in different zones.

Across all metrics of mangrove, environmental status provided in Table 2-12, there was a regular decline in the total number of scores indicating a least impacted environment from Whangateau estuary (8) in the north to Tamaki estuary (4) in the south.

Table 12: Assessment of mangrove habitat in five estuaries using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted estuary are highlighted for each metric

Assessment metric	Whangateau	Mahurangi	Puhoi	Waiwera	Tamaki
Total number of threats active in this habitat	39	41	31	36	37
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	1.05	1.09	0.95	1.05	1.16
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.24	2.35	2.40	2.36	2.50
Mean certainty for threats active in this habitat (range 0-1)	0.35	0.41	0.37	0.35	0.35
Number of 1° invasive species	0	0	0	0	0
Number of 2° invasive species	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4	4	4	4	3.03
Sediment quality, mean score (range 0-4 high)	3.75	3.37	3.66	3.66	2.53
Biota, mean score (range 0-4 high)	3	2	2	2	2
Habitat quality, mean score (range 0-4 high)	3	3	3	3	3
Ecosystem G & S, Regulatory mean score (range 0-4 high)	2.71	3.5	3.15	3.25	3.30
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.57	1.00	0.5	0.83	0.5
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.63	2.06	2.33	2.33	1.66
Number of endangered species in habitat	5	0	2	2	10
Total number of least impact scores	*8*	*7*	*6*	*4*	*4*

2.6 Apply agreed methodology across the habitat assessments completed for Whangateau estuary

We applied the agreed methodology across 41 assessments of habitats in three zones (upper A and B and middle) in Whangateau estuary to produce a single combined assessment for each habitat (Table 2-13), which accounts for the relative areas of each habitat in the estuary. However, in most respects the results differ little from those presented earlier for habitats in each zone of Whangateau estuary (Section 2.5) as there was little contrast in these assessments among zones, and nine habitats occurred in only a single zone. The major difference was that in some cases the number of human threats active in each habitat is higher than the individual zone totals as different threats sometimes occurred in different zones.

Several metrics provided no contrast among habitats: the number of 1^{o} invasive species and the assessments of water quality, sediment quality, biota and overall habitat quality had the same score across all habitats.

Across all metrics provided in Table 2-13 intertidal sand was clearly the least impacted habitat as indicated by eleven of the 14 metrics, followed by cockle shell habitat as indicated by nine metrics. All other habitats scored very similarly.

We also combined assessments across all habitats to come up with a single assessment for Whangateau estuary (see final column in Table 2-13). This combined assessment takes into account the relative areas of each habitat in the estuary and generally reflects the assessments for intertidal sand, hard-packed sand, and mangrove as together these habitats account for 87% of the estuary area. Noteworthy in this combined assessment are the 50 threats identified as active in Whangateau estuary; a total that is much higher than the largest number identified in a single habitat. The vulnerability assessments indicate that overall Whangateau estuary is only moderately affected by these threats but that the average level of confidence in this vulnerability assessment was modest. However, the number of invasive species was low, water quality excellent, and sediment quality only marginally less so. The assessment of biota indicated that all expected species were present but not all size or age classes. The overall assessment of habitat quality (a score of 3 out of a possible 4) indicated that many but not all habitat features and/or functions were present. Levels of production of regulatory and non-consumptive ecosystem services were high to moderate while levels of production of provisioning services were low.

Table 13: Assessment of total area of all habitats in Whangateau estuary using 14 metrics generated by the MarHADS tool

Scores indicating the least impacted habitat are highlighted for each metric. Note this table continues on the following page

Assessment metric	Saltmarsh	Beach-shelly	Mangrove	Intertidal sand	Rubble on sand	Reef	Hard packed sand	Sand bank	Seagrass	Minor channel
Total number of threats active in this habitat	25	22	39	41	20	29	33	29	28	28
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.70	0.75	1.05	0.95	0.60	0.84	0.85	0.73	0.93	0.79
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.26	2.50	2.2	1.94	2.18	2.23	2.14	2.11	2.44	2.27
Mean certainty for threats active in this habitat (range 0-1)	0.27	0.27	0.3	0.32	0.29	0.29	0.31	0.34	0.38	0.31
Number of 1° invasive species	0	0	0	0	0	0	0	0	0	0
Number of 2° invasive species	1	0	1	0	1	1	1	1	1	1
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Sediment quality, mean score (range 0-4 high)	3.67	3.67	3.75	3.67	3.67	3.67	3.67	3.67	3.67	3.67
Biota, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Habitat quality, mean score (range 0-4 high)	3.00	2.79	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Ecosystem G & S, Regulatory mean score (range 0-4 high)	3.02	1.38	2.71	3.32	1.75	1.27	1.92	2.12	3.08	1.39
Ecosystem G & S, Provisioning mean score (range 0-4 high)	0.55	0.80	0.57	1.14	0.33	0.77	0.67	0.83	1.00	0.37
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	1.97	1.68	2.63	2.70	0.56	1.60	1.15	1.89	2.11	0.86
Number of endangered species in habitat	2	4	5	6	5	3	0	5	3	0
Total number of least impact scores	*4*	*4*	*5*	*10*	*6*	*4*	*4*	*4*	*5*	*4*
Area (ha)	5.466	5.617	114.24	411.157	0.487	6.041	123.624	7.964	35.359	14.508
Proportion of Whangateau estuary	0.007324	0.007527	0.153090	0.550957	0.000653	0.008095	0.1656583	0.010672	0.047382	0.019441

Table 13: continued

Assessment metric	Cockle shell	Reef with Sand	Subtidal Rock/ shell/sand	Subtidal Sand	Subtidal sand & shell	Subtidal Shell	Subtidal Weed on rock	Whangateau Combined
Total number of threats active in this habitat	25	26	22	28	29	29	26	**50**
Mean vulnerability score over all threats listed in this tool (range 0-4 high)	0.80	0.80	0.64	0.79	0.82	0.83	0.79	**0.93**
Mean vulnerability score for threats active in this habitat (range 0-4 high)	2.34	2.26	2.14	2.05	2.05	2.09	2.21	**2.08**
Mean certainty for threats active in this habitat (range 0-1)	0.30	0.31	0.29	0.30	0.28	0.29	0.30	**0.32**
Number of 1° invasive species	0	0	0	0	0	0	0	**0**
Number of 2° invasive species	1	1	1	1	1	1	1	**1**
Water quality, mean score (range 0-4 high)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	**4.00**
Sediment quality, mean score (range 0-4 high)	3.67	3.67	3.67	3.67	3.67	3.67	3.67	**3.67**
Biota, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	**3.00**
Habitat quality, mean score (range 0-4 high)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	**3.00**
Ecosystem G & S, Regulatory mean score (range 0-4 high)	2.50	1.25	1.50	1.75	1.75	1.75	1.58	**2.85**
Ecosystem G & S, Provisioning mean score (range 0-4 high)	1.00	0.83	0.67	0.67	0.67	0.67	0.33	**0.92**
Ecosystem G & S, Non-consumptive mean score (range 0-4 high)	2.44	1.44	0.89	1.44	1.44	1.44	1.22	**2.31**
Number of endangered species in habitat	4	3	0	0	0	0	0	**6**
Total number of least impact scores	*4*	*4*	*4*	*4*	*4*	*4*	*4*	**-**
Area (ha)	4.458	0.004	0.006	6.104	1.857	9.109	0.253	**746.259**
Proportion of Whangateau estuary	0.005974	0.000005	0.000009	0.008179	0.002488	0.012206	0.000339	**1.0**

3 Discussion and conclusions

The principal objectives of this project were to test the MarHADS tool by applying it to selected habitats within the AC region for which sufficient detailed information was available, and to develop and apply a methodology that combines individual assessments into larger scale assessments. The MarHADS tool was successfully applied to mangrove habitats in three zones within five estuaries, seagrass beds in three of these estuaries, and to 17 benthic habitats occurring in three zones in Whangateau estuary. Although it would have been desirable to apply the tool to a wider range of habitats at different locations this was not possible within the project timeframe. However, the application of the tool was sufficient to test its effectiveness.

The five estuaries selected for assessment of mangrove habitats were initially chosen because it was widely understood they lay on an impact gradient with Whangateau estuary in the north having the most pristine environment and Tamaki estuary in the heart of Auckland City being the most heavily impacted by human activities. Although the contrast was not great, the zonal assessments indicated that Whangateau and Tamaki estuaries lay at either end of this gradient but the three intermediate estuaries varied in their position on this gradient depending on the zone considered. A possible reason for the rather opaque outcome of the zonal assessments was the difficulty experienced by AC staff in dividing each estuary into zones which would allow meaningful comparisons within and among estuaries. This was especially the case as some estuaries were large and complex with many arms, and other estuaries were small and simple. The three-zone model tested here resulted in comparisons of zones among estuaries that from a hydrodynamic point of view were very different.

Assessment of the zones within the estuaries could be made more useful by taking into account the different configuration of estuaries; however, this needs to be mindful of adding undue complication for the application of the MarHADS tool. Rather than three rather arbitrary zones as used here, the Strahler stream order system (Strahler 1957), for example, could be used to divide the larger and more complex estuaries into a larger number of upper or 1st order arms, each associated with a defined tributary, that feed into a lesser number of 2nd order arms and so on leading to the outermost and highest order arm. By using this system, simple estuaries such as the Puhoi estuary would be classified as comprising a single 1st order arm while the larger and more complex Mahurangi estuary would have approximately 16 1st order arms, three 2nd order stretches and so on. Comparisons of habitats could then be made among arms of the same order within and/or among estuaries. Gleyzer et al. (2004) describe a GIS application used to compute Strahler stream order values. The exact application of a tool such as the Strahler system needs to weigh up increased precision against added complication to prevent the use of the MarHADS tool from becoming too unwieldy. The same system of calculated stream order could simply allow informative comparisons among similar scoring estuaries. Assessment of zones and estuary configuration requires further investigation; the Strahler stream order system is one approach that could assist in this process.

In the seagrass assessments, although water quality, sediment quality, and biota were all highest for Whangateau estuary and lowest for Tamaki estuary, other metrics were not as clear with the result that there was only a marginal difference in the total numbers of least impact scores among the estuaries assessed. This lack of contrast may be because of the differing location of the extant seagrass beds in the estuaries (in Tamaki and Mahurangi they were located in the outer zone while in the Whangateau they were located in an upper zone). A broader assessment of seagrass habitats, including those in estuaries on Great Barrier Island, is probably required to identify the extremes of seagrass status within the Hauraki Gulf.

The application of the MarHADS tool to 17 benthic habitats within three zones in Whangateau estuary clearly indicated that intertidal sand flats were the least impacted habitat at this locality while mangroves were among the habitats most affected by human activities. This result was not evident before the assessments had been undertaken and may stem from the position of mangroves around the estuary margins where they are accessible and more vulnerable to human activity. This accessibility and vulnerability of mangroves indicates they were a good choice for the initial comparison of the tool assessments among estuary systems.

The lack of any significant relationship between mean vulnerability score and mean certainty score for all active threats in mangroves across estuaries (Figure 2-6), and in habitats across zones in Whangateau estuary (Figure 2-7), suggests that the assessment scores and the conclusions drawn from them were not significantly or consistently affected by the quality of the available information.

During a workshop with AC staff, it was agreed that two methods should be used to combine scores across habitats within a defined sub-region. For most of the output assessment metrics, each score would be weighted by its proportional contribution to the total area of the sub-region, and all weighted scores then summed to calculate the sub-region score. For four metrics, a simple count is required across assessments to identify the number of all active threats, 1º and 2º invasive species, and the number of endangered species. In these cases, it would be inappropriate to weight the individual habitat scores by the proportional area of the habitat.

The combined assessment of mangrove habitat within each estuary as a whole provided a clear indication of a probable impact gradient in the western Hauraki Gulf (Table 2-12), with a regular decline in the total number of scores indicating a least impacted environment from Whangateau estuary (8) in the north to Tamaki estuary (4) in the south. Nine of the 14 metrics contributed towards this result: the number of active threats, the mean vulnerability score based on this subset of threats, water quality, sediment quality, the assessment of biota, the three classes of ecosystem goods and services, and the number of endangered species. The other metrics provided little or no contrast (see further discussion below). This result underscores the usefulness of combining assessments within a locality when making comparisons among localities.

However, overall the metrics of mangrove habitat showed less contrast than may have been expected across the five estuaries. This was probably because the assessments indicated that although Whangateau estuary had the least impacted mangrove habitat, this habitat was nevertheless threatened by a considerable number of human activities and was not pristine. The

mangrove habitat in Tamaki estuary, despite numerous threats and shown by the MarHADS tool to be in a poorer ecological state than Whangateau mangroves, was less degraded than might have been expected before the assessments were undertaken.
Scores across 41 assessments of habitats in three zones (upper A and B and middle) in Whangateau estuary were combined to produce a single assessment for each habitat. This produced results that differed little from those for habitats in each zone of Whangateau estuary as there was little contrast in these assessments among zones, and nine habitats occurred in only a single zone. The major difference was that in some cases the number of human threats active in each habitat was higher than the individual zone totals as different threats sometimes occurred in different habitats.

The assessments undertaken indicated the effectiveness of the different metrics in different situations. The number of active threats, the mean vulnerability score based on these active threats and the three ecosystem services provided contrast among zones for the same habitat, among estuaries for the same habitat, and among habitats in the same estuary. Quantitative assessment of marine ecosystem goods and services is still at an early stage in New Zealand but the need is likely to increase (MacDiarmid et al. 2013, Thrush et al. 2013). Because the MarHADS tool uses a categorical evaluation of the level of ecosystem service provided by a habitat it can take advantage of any future development in ecosystem service quantification.

Assessments of water quality, sediment quality, and biota provided little or no contrast within zones or estuaries because they were usually based on limited sampling within estuaries, but were effective at providing contrast among estuaries. The overall assessment of habitat quality that indicates the degree to which expected ecosystem features and functions remained in operation, provided little contrast across habitats, zones or estuaries. This metric should be re-examined to determine if more or different levels should be introduced, whether it should be applied differently, or dropped entirely.

The number of invasive species present in a habitat provided no contrast within or among estuaries principally because at present this measure is based largely on regional scale information. Increased information about the actual or likely (modelled) presence of invasive species on a smaller spatial scale would make this metric more relevant to regional scale assessments. Also unhelpful was the assessment of mean habitat vulnerability across all threats listed in the MarHADS tool, even those that are not present in a habitat, zone or estuary. This metric down-weights the contribution of active threats and was confusing to interpret. Consideration should be given to dropping this metric from the usual list of metrics reported from the tool.

To be effectively implemented the MarHADS tool requires a great deal of knowledge and information about particular habitats at identified localities. Knowledge is required about the spatial distribution of the environment being assessed, which in most cases is displayed in a habitat map. Knowledge of the likely threats to a habitat, their scale and functional impact, as well as the resilience of the habitat to those particular threats, and the recovery timescale once the threat is removed is required. Also necessary is information about the presence of nationally threatened and at risk species, the number of invasive species, water quality, sediment quality, the degree to which the expected biotic assemblage remains intact, and an overall assessment of the degree to which expected ecosystem features and functions remain in operation. Knowledge about the level of regulatory, provisioning, and non-consumptive ecosystem goods and services provided by the assessed habitats, although desirable, is not essential as national defaults for these values can be used, though these remain to be tested and compared against local information.

The amount of information required to properly implement the MarHADS tool is probably little different from that needed to effectively assess terrestrial or freshwater habitats. However, in marine areas the lack of even basic environmental information, such as a map of habitat distributions for a region, is commonplace. Unfortunately, this lack of information about the extent of marine habitats, the distribution and abundance of most species, and the state of the marine environment is a general and serious problem nationwide that hampers efforts by every agency to effectively manage its marine estate and resources (MacDiarmid et al. 2012). The data requirements of the MarHADS tool underscore the need for more effort to overcome the deficit in information regarding New Zealand's marine environment.

Our experience in this project indicates that familiarisation with the available information is a key to rapid application of the tool. The NIWA team member who undertook the assessments (JS-D) was initially unfamiliar with the localities or habitats assessed and it took time to become acquainted with the extent and complexities of the relevant available information and data. The review of a subset of the preliminary assessments by AC staff familiar with these habitats was a useful process that resulted in more consistent application of the tool across all assessments. Initial application of the tool by experienced and knowledgeable AC coastal scientists should be more straightforward but a review of a subset of assessed habitats by other experienced staff should be standard practice to ensure consistent application.

4 Recommendations

Several recommendations arise from this first application of the MarHADS tool.

1. Ideally, the tool should be applied by a small and consistent group of people, of which at least one should have good local knowledge and experience of the area being assessed.
2. The tool should be applied in conjunction with the operating manual to help ensure that the same definitions of threats, certainty, smallest and intermediate areas of interest, etc. are used by all assessors.
3. Comments fields in the tool or insertion of comments in cells should be routinely used and include supporting references, so that decisions can be understood by someone not part of the assessment process or at a later date.
4. A subset of preliminary assessments should be reviewed by other experienced staff independent of the assessment team to ensure consistent application. Insights gained from this review should then be applied across all assessments.
5. The tool makes best use of information collected on a habitat patch (e.g. seagrass bed, shellfish bed, mangrove forest) scale as then assessments can be undertaken at the desired level and combined for comparisons on a larger scale.
6. The assessment of threats should be restricted only to those that are occurring within or having a direct impact on the habitat being evaluated.
7. Further consideration should be given to how estuarine systems could be divided into zones to better assist comparisons of habitats within and among estuaries. This needs to weigh up precision against complication, and also to keep the tool from becoming too unwieldy. The Strahler stream order system is one tool that could allow informative comparisons among orders of estuaries, and warrants further investigation.
8. The methods developed jointly with AC staff to combine scores across assessments should be adopted and applied nationally.
9. The overall assessment of habitat quality that indicates the degree that expected ecosystem features and functions remained in operation provided little contrast across habitats, zones or estuaries. This metric should be re-examined to determine if more or different levels should be introduced, whether it should be applied differently, or dropped entirely.
10. At present, the presence of invasive species is based largely on regional scale information and provides no contrast within or among estuaries. Better information about the actual or likely (perhaps modelled on the basis of larval transport and habitat requirements of key species) presence of invasive species on a smaller spatial scale would make this metric more relevant.
11. Consideration should be given to dropping the assessment of mean habitat vulnerability across all threats from the usual list of metrics reported from the tool. It down-weights the contribution of active threats and was confusing to interpret.
12. Modest funding is required to undertake further work on the tool to:
    - Make it easier to extract and sum the number of active threats, numbers of 1^{o} and 2^{o} invasive species, and the number of threatened species across assessments;

- Update the embedded list of invasive species at each port;
- Update the embedded list of threatened species;
- Update the embedded national habitat area totals as new data become available.

5 Acknowledgements

Many thanks to Dr Megan Carbines, Marcus Cameron, Dr Jarrod Walker, and Melanie Vaughan of Auckland Council for providing the raw material for the assessments, reviewing the preliminary assessments and for their organising of, and participation in, the workshops. David Thompson (NIWA), Melanie Vaughan, Megan Carbines, and Mike Hudson (all AC) provided many useful comments on the draft report.

6 References and bibliography: Published and unpublished information sources consulted to undertake assessments

Anderson, M.J., Pawley, M.D.M., Ford, R.B., Williams, C.L. (2007) Temporal variation in benthic estuarine assemblages of the Auckland region. Prepared by UniServices for Auckland Regional Council. Auckland Regional Council Technical Publication, 348: 102.

Auckland Council. GIS maps http://maps.aucklandcouncil.govt.nz/aucklandcouncilviewer/ Auckland Council. Accessed 9-Jun-2013, Parks- Tahuna Torea, http://www.aucklandcouncil.govt.nz/EN/parksfacilities/walkingtracks/Pages/tahunatoreawalkingtrails.aspx

Auckland Council. Auckland unitary plan: Frequently asked questions– Significant ecological areas (SEAs): 2

Auckland Council (2012). State of Auckland, marine report card: Tamaki estuary reporting area: 2

Auckland Council (2011). State of the Auckland Region, marine report card: Mahurangi harbour reporting area: 2.

Auckland Council (2011). State of the Auckland Region, marine report card: Tamaki estuary reporting area: 2.

Auckland Council (2011). Decision following the hearing of objections to conditions of resource consents held on 30 Sept. 2011: Objections under Section 357 of the Resource Management Act 1991 by Coromandel Marine Farmers' Association, Westpac Mussel Farms Ltd, Ambush Marine Farms Ltd and Dean Aislabie, Waiheke Mussel Company Limited and South Pacific Oysters Limited to reviewed conditions of resource consent for various marine farms at Mahurangi, Clevedon, Waimangu Point, Waiheke Island and Great Barrier Island, P/004200/1/1: 16.

Auckland Council. New Zealand's mangroves, information brochure: 2.

Auckland Regional Council. Coastal planting guide: Coastal wetlands, saltmarshes and estuaries, 5: 4.

Auckland Regional Council (2010) Fact sheet: Te Muri regional park– New parkland for Auckland region: 2.

Brooks, D. (2012) Much ado about nothing. Forest and bird. http://www.forestandbird.org.nz/what-we-do/publications/forest-bird-magazine-article/much-ado-about-nothing.

Chiaroni, L., Hewitt, J.E., Hailes, S.F. (2010) Tamaki Strait: Marine benthic habitats, ecological values and threats. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council Technical Report, 2010/038: 95.

Cummings, V., Hewitt, J., Wilkinson, S., Thrush, S., Turner, S. (2009). Mahurangi Harbour biological monitoring programme: Report of data collected during the first year of monitoring. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council Technical Report, 2009/039: 29.

de Juan, S., Thrush, S.F., Hewitt, J.E. (2013). Counting on β-Diversity to safeguard the resilience of estuaries. PLoS ONE, 8(6): e65575. doi: 10.1371/journal.pone.0065575

Department of Conservation. Maps R09 and R10: Areas administered by the department of conservation. Prepared by Auckland Regional Council for the Department of Conservation.

Department of Conservation (2010). New Zealand Coastal Policy Statement 2010. See http://doc.org.nz/documents/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement-2010.pdf

Draft Auckland unitary plan, March 2013. Appendix 6.2: Schedule of areas of outstanding and high natural character, Coastal: 103.

Draft Auckland unitary plan, March 2013. Appendix 6.1: Schedule of significant ecological areas-Marine: 38.

Duarte, C.M. (2002). The future of seagrass meadows, Foundation for Environmental Conservation. 29 (2): 192-206.

Foster, E. (2013). Sewage entering harbour: Harbourcare submission to Auckland Council regarding sewage treatment entering Whangateau Harbour. Whangateau Harbourcare. http://whangateauharbour.org/harbourcare-submission-to-auckland-council-regarding-sewerage-treatment-entering-whangateau-harbour/

Froude, V.A., Smith, R. (2004). Area-based restrictions in the New Zealand marine environment. Department of Conservation MCU Report, ISBN 0-478-22644-6: 161.

Gleyzer, A., Denisyuk, M., Rimmer, A., Salingar, Y. (2004), A fast recursive GIS algorithm for computing Strahler stream order in braided and nonbraided networks. Journal of the American Water Resources Association 40 (4): 937–946, doi:10.1111/j.1752-1688.2004.tb01057.x

Grace, R. (2013). What happens when you dig a hole in an estuary? Preliminary results from experimental sediment traps in Whangateau and Matakana Estuaries. Presented to Auckland Council Environment and Sustainability Forum. July 22nd 2013.

Grace, R. (2012). Mangrove seedling removal trial at Whangateau harbour. http://whangateauharbour.org/2012/10/14/mangrove-seedling-removal-trial-at-whangateau-harbour/

Grace, R. (2012). Whangateau Harbourcare. Published 7-Nov-2012, Orca make lunchtime raid on rays of Whangateau, http://whangateauharbour.org/2012/11/07/orca-make-lunchtime-raid-on-rays-of-whangateau/

Grace, R.V. (1971) A checklist of fishes from the entrance to the Whangateau harbour, Northland, New Zealand. Tane, 17: 129-136.

Haggitt, T., Mead, S., Bellingham, M. (2008). Review of environmental information on the Kaipara Harbour marine environment. Prepared by ASR/CASL for Auckland Regional Council. Auckland Regional Council Technical Publication, 354: 190.

Halliday, J., Cummings, V. (2012). Mahurangi estuary ecological monitoring programme: Report on data collected from July 1994 to January 2011. Prepared by the National Institute of Water and Atmospheric Research for Auckland Council. Auckland Council Technical Report, 2012/003: 127.

Hansen, K. (2006). New Zealand fairy tern (*Sterna nereis davisae*) recovery plan, 2005-15. Science and Technical Publishing, Department of Conservation: 31.

Hauraki Gulf Forum (2011). State of our gulf: Tikapa moana– Hauraki gulf: 164.

Hayward, B.W., Morley, M.S. (2005). Intertidal life of the Tamaki Estuary and its entrance, Auckland. Prepared for Auckland Regional Council. Auckland Regional Council Technical Publication, 373: 72.

Hewitt, J., Simpson, J. (2012). Assessment of the estuarine ecological monitoring programme to 2012. Prepared by the National Institute of Water and Atmospheric Research for Auckland Council. Auckland Council Technical Report, 2012/040: 66.

Hewitt, J. (2007). Marine Ecology: Does seagrass contribute to marine biodiversity? Water and Atmosphere. National Institute of Water and Atmospheric Research: 18-19.

Hicks, D., Hawcridge, E. (2004). A survey of sediment sources on the streams in the Mahurangi catchment. ARC-TP270: 13.

Hughes, R.A., Williams, S.L., Duarte, C.M., Heck, K.L., Waycott, M. (2009). Associations of concern: declining seagrasses and threatened dependent species. Frontiers in Ecology and the Environment, 7(5): 242-246. doi: 10.1890/080041

Jones, H.F. (2011) The ecological role of the suspension feeding bivalve, *Austrovenus stutchburyi*, in estuarine ecosystems. Biological Sciences. University of Waikato: 162.

Kelly, S. (2009). Whangateau catchment and harbour study: Review of marine environment information. Prepared for Auckland Regional Council. Auckland Regional Council Technical Report, 2009/003: 68.

Kelly, S. (2008). Environmental condition and values of Mangere Inlet, Whau Estuary and Tamaki Estuary. Prepared by Coast and Catchment Ltd. for Auckland Regional Council. Auckland Regional Council Technical Report, 2008/031: 130.

Lees, A., Cole, J. (2009). Whangateau catchment and harbour study: Review of Iwi and stakeholder information. Prepared for Auckland Regional Council. Auckland Regional Council Technical Report, 2009/005: 38.

Lohrer, D., Townsend, M., Morrison, M., Hewitt, J. (2008). Change in the benthic assemblages of the Waitemata Harbour: Invasion risk as a function of community structure. Prepared by the National Institute of Water and Atmospheric Research for BNZ Pre-clearance Directorate. Biosecurity New Zealand Technical Paper, 2008/17: 54.

Lovegrove, T., Zeiler, C., Greene, B., Green, B., Gaastra, R., MacArthur, A. (2002). Alien plant and animal control and aspects of ecological restoration in a small 'mainland island': Wenderholm Regional Park, New Zealand. In: C. Veitch & M. Clout (Eds). Turning the tide: The eradication of invasive species. IUCN SSC Invasive Sepcies Specialist Group, Gland, Switzerland and Cambridge, UK: 155-163.

Lundquist, C.L. (2011). Waikato Regional Council, rivers and catchment services. Whangamata harbour mangrove removal assessment: Effects on benthic and aquatic ecology. Statement of evidence of Carolyn Jean Lundquist, 9-September-2011, in the matter of resource consent applications 122986 and 122987: 18

Macaskill, J., Martin, M. (2004). Water quality surveys of Mahurangi Harbour, Upper Waitemata Harbour and Tamaki Estuary: Annual report- January-December 2003. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council Technical Publication, 235: 198.

MacDiarmid, A.B., Thompson, D., Pinkerton, M., Hume, T. (2012). Scoping analysis of matters to consider when reporting on the state of marine environment. NIWA Client Report No. WLG12-31, 106 p.

MacDiarmid, A.B., Law, C.S., Pinkerton, M., Zeldis, J. (2013). New Zealand marine ecosystem services. In Dymond, J.R. ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

Matheson, F., Dos Santos, V., Inglis, G., Pilditch, C., Reed, J., Morrison, M., Lundquist, C., Van Houte-Howes, K., Hailes, S., Hewitt, J. (2009). New Zealand seagrass- General information guide. NIWA Information Series, 72: 13.

Mills, G., Williamson, B., Cameron, M., Vaughan, M. (2012). Marine sediment contaminants: Status and trends assessment 1998 to 2010. Prepared by Diffuse Sources Ltd for Auckland Council. Auckland Council technical report TR2012/041; 104.

Ministry for Primary Industries. Updated 24-Dec-2012, Closed and restricted areas, http://www.fish.govt.nz/en-nz/Recreational/Fishery+Management+Areas/Auckland+and+Kermadec+Areas/Closed+and+Restricted+Areas.htm

Ministry for Primary Industries. Marine Biosecurity Porthole. http://www.marinebiosecurity.org.nz/

Ministry of Fisheries (2010). Recreational fisher's handbook, October 2009-October 2010: 94.

Morrison, M., Francis, M. (2005) Fish survey: Update on NIWA survey of fish communities in mangroves and seagrass meadows. Water and Atmosphere. National Institute of Water and Atmospheric Research. https://www.niwa.co.nz/publications/wa/vol13-no2-june-2005/4-fish-survey

Morrison, M., Patuawa, T., World Wildlife Fund. Accessed 7-Jun-2013, Treasures of the sea-mangroves and seagrasses (Phylum Tracheophyta, Class Angiospermae), http://www.treasuresofthesea.org.nz/mangroves-and-seagrasses

Needham, H.R., Lundquist, C. (2012). Review of mapped intertidal habitat information for the Hauraki Gulf. Prepared by the National Institute of Water and Atmospheric Research for Department of Conservation, DOC12215: 70.

New Zealand Biodiversity Strategy (2000). See http://www.biodiversity.govt.nz/pdfs/picture/nzbs-whole.pdf

Northland Regional Council. Accessed 24-May-2013. Mangroves: Forests of the harbour, http://www.nrc.govt.nz/for-schools/school-information-packs/mangroOrth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck jr. K.I., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M., Williams, S.I. (2006). Global crisis for seagrass ecosystems. Bioscience 56(12): 987-996.

Rodney District Council (2010). Puhoi structure plan– Draft, July: 49.

Schwarz, A.-M., Matheson, F., Mathieson, T. (2004). Coastal ecosystems: The role of sediment in keeping seagrass beds healthy. Water and Atmosphere. National Institute of Water and Atmospheric Research: 18-19.

State of the environment and biodiversity (2009). Section 4.4, Marine: 181-199.

Strahler, A. N. (1957). Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38 (6): 913–920

Swales, A.; Bell, R.G.; Gorman, R.; Oldman, J.W.; Altenberger, A.; Hart, C.; Calydon, L.; Wadhwa, S.; Ovenden, R. (2009). Potential future changes in mangrove habitat in Auckland's east-coast estuaries. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2009/079.

Swales, A., Gibbs, M., Ovenden, R., Costley, K., Hermansphan, N., Budd, R., Rendle, D., Hart, C., Wadhwa, S. (2011). Patterns and rates of recent sedimentation and intertidal vegetation changes in the Kaipara Harbour. Prepared by the National Institute of Water and Atmospheric Research for Auckland Council and Northland Regional Council. Auckland Regional Council, ARC10224: 135.

Swales, A., Gibbs, M., Ovenden, R., Budd, R., Hermansphan, N. (2008). Sedimentation in the Okura- Weiti- Karepiro bay system: progress report. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council, ARC08220: 40.

Swales, A., Hume, T.M., Oldman, J.W., Green, M.O. (1997). Holocene sedimentation and recent human impacts on infilling in a drowned valley estuary. Coasts and Ports, 2: 895-900.

Swales, A., Hume, T., McGlone, M., Pilvio, R., Ovenden, R., Zviguina, N., Hatton, S., Nicholls, P., Budd, R., Hewitt, J., Pickmere, S., Costley, K. (2002). Evidence for the physical effects of catchment sediment runoff preserved in estuarine sediments: Phase II (field study). Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council Technical Publication, 221: 50.

Swales, A., Stephens, S., Hewitt, J., Ovenden, R., Hailes, S., Lohrer, D., Hermansphan, N., Hart, C., Budd, R., Wadhwa, S., Okey, M. (2007). Central Waitemata harbour contaminant study- Harbour sediments. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council, ARC07243: 92.

Swales, A., Williamson, R.B., Van Dam, L.F., Stroud, M.J., McGlone, M.S. (2002). Reconstruction of urban storm water contamination of an estuary using catchment history and sediment profile dating. Estuaries, 25(1): 43-56.

Thrush, S.F., Townsend, M., Hewitt, J.E., Davies, K., Lohrer, A.M., Lundquist, C., Carter, K. (2013) The many uses and values of estuarine ecosystems. In Dymond, J.R. ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

Townsend, M., Hailes, S., Hewitt, J.E., Chiaroni, L.D. (2010). Ecological communities and habitats of Whangateau Harbour, 2009. Prepared by the National Institute of Water and Atmospheric Research for Auckland Regional Council. Auckland Regional Council Technical Publication, 2010/057: 44.

Troup, C. (2012). Marine invaders- Invasive marine algae and plants in New Zealand. Te Ara- The encyclopedia of New Zealand. http://www.TeAra.govt.nz/en/marine-invaders/page-1

Turner, S., Schwarz, A. (2006). Management and conservation of seagrass in New Zealand: an introduction, Ed. Helen O'Leary. Science and Technical Publishing, Science for Conservation 264: 90. Whangarei District Council and Department of Conservation. Whangarei terenga paraoa- Whangarei harbour, poster: 1.

Whangateau Harbourcare. Accessed 26-May-2013, To sustain the environment of the Whangateau harbour and its catchment, http://whangateauharbour.org/harbourcare-submission-to-auckland-council-regarding-sewerage-treatment-entering-whangateau-harbour/

Whangateau Harbourcare. Accessed 26-May-2013, 10 point protection plan for Whangateau harbour, http://whangateauharbour.org/10-point-plan

Appendix: Assessment of vulnerability worksheets

Threats	**General Comments:** Processing the "Vulnerability" worksheets in MarHADS requires a solid background knowledge of the estuaries being assessed and a good grounding in marine ecology which enables considered subjective and objective comments. These comments in turn feed into the certainty score. Filling in the "Vulnerability" worksheet incorporates both subjective and objective judgement in combination with published information. In relation to the threats of coastal reclamation, causeways, pontoons, piled wharfs/sheds, pile moorings/markers, seawalls and pipelines scoring was based on objective assessment by studying Google maps especially. Access by foot or vehicles to any of the scored habitats within the estuaries was also determined by scrutinising Google maps.
Fishing:	
Bottom trawling	NA
Scallop or oyster dredging	NA
Potting or trapping for fish or crays	NA
Paua gathering	NA
Seaweed gathering	NA
Spear fishing	This is an unlikely activity in most estuaries assessed other than perhaps where there are reefs.
Set netting	No commercial fisher shall use for taking fish a box or teichi net, purse seine net, Danish seine net, trawl net, or lampara net, or set nets of a total length exceeding 1 000 metres, in the following waters: Tamaki & Whangateau See http://www.fish.govt.nz/en-nz/Recreational/Set+nets/net+design+and+construction.htm and http://www.legislation.co.nz/regulation/public/1986/0216/34.0/DLM104498.html
Pelagic low bycatch (e.g. squid jigging)	NA
Pelagic high bycatch (e.g. mid-water trawling)	NA
Long-lining	NA
Shellfish gathering	Presently prohibited in Whangateau and subject to certain restrictions and intermittent closures in the other estuaries. See http://www.legislation.co.nz/regulation/public/1986/0216/latest/resultsin.aspx?search=sw_096be8ed80b9e14a_shellfish_25_se&p=1
Recreational line fishing	Line fishing occurs from wharfs and reefs and from boats in all the estuaries

Altered river inputs:

Decreased sediment loading	Generally NA
Increased sediment loading (land use)-chronic	Occurrence and the extent of sediment loading are variable and uncertain for most estuaries. Clearly adjacent farming and recreational developments will add to sedimentation of the estuaries to some degrees as well as the extent of catchment areas. In some instances long term monitoring has provided data on sedimentation. For the Mahurangi subtidal sediment loading has been recognised as having adverse effects on benthic communities (see Halliday and Cummings (2012). Whangateau Harbourcare have undertaken some sediment trap work which indicates periods of heavy sediment loading in this estuary (see http://www.aucklandcouncil.govt.nz/SiteCollectionDocuments/aboutcouncil/committees/environmentsustainabilityforum/meetings/environmentandsustainabilityforumminit5a20130722.pdf
Increased sediment loading (land use)-pulsed	There are no data on pulsing events although after heavy rains, such events are likely to occur. However having no data delivers a low certainty score
Decreased freshwater discharge	Generally NA
Increased freshwater discharge	There is no data on increased freshwater discharges although after heavy rains, such events are likely to occur. However having no data delivers a low certainty score
Dampening of flows	The occurrence of this threat was scored in relation to the likelihood of flow restrictions brought about by engineering works
Engineering works:	
Sand / gravel abstraction	Generally NA or if scored, a low certainty was ascribed
Dredging	Generally NA or if scored, a low certainty was ascribed
Mineral extraction - surface suction	NA
Mineral extraction - deep hole extraction	NA
Minerals extraction - other methods	NA
Dumping of dredge spoils	Generally NA or if scored, a low certainty was ascribed
Coastal reclamation	There is some ambiguity in scoring this threat as land reclamation is more often historical and the estuarine system has 'adjusted to incorporate such change. The approach taken in this report is to consider whether land reclamation (recent or historical) is a present ongoing threat to the scored habitat. For instance in the Whangateau estuary the causeway, built around 1970, continues to restrict flow to and thus impact habitats in the Upper A zone

	(Figure 2.1). Here a score of "medium' for impact and certainty would be ascribed. In other areas the impact of land reclamation would score with less certainty.
Causeways	These were located through Google Maps and assessed depending on their location and extent of imposition on a habitat
Pontoons	These were located through Google Maps and assessed depending on their location and extent of imposition on a habitat
Piled wharfs/sheds	These were located through Google Maps and assessed depending on their location and extent of imposition on a habitat
Pile moorings/ markers	These were located through Google Maps and assessed depending on their location and extent of imposition on a habitat
Seawalls	These were located through Google Maps and assessed depending on their location and extent of imposition on a habitat
Pipelines	These were located through Google Maps and assessed depending on their location and extent of imposition on a habitat

Climate change:

All climate change scores were generally the same for all habitats in all estuaries. The percentage of habitat impacted by global climate change would be >50%, threat frequency = persistent, impact = minor in most instances, Habitat Susceptibility to Threat = entire ecosystem, threat frequency = 10-100 yrs and certainty =low. An exception was for mangroves where the impact of sea level rise would be devastating and so certainty was scored at 'medium'

Pollution from various sources e.g storm water, ground water, spills etc:

Heavy metals-chronic	In the Mahurangi, sampling carried out in 2010 showed levels of lead, copper, zinc and PAHs found in sediment were generally very low across all six sites sampled across whole harbour all fell within the ERC green category (Mills et al 2012). In Whangateau, copper, zinc and mercury levels in sediments have at times exceeded national standards (Kelly 2009). In Tamaki Auckland Council tests for zinc, copper and lead every 2-5 years. Other contaminants such as PAHs (by-products of burning fuels) and arsenic are also Monitored: some elevation in these contaminates from some of the sampling sites does occur.
Heavy metals-pulsed	No data available for any of the estuaries on pulsing contamination. A subjective view was adopted in assuming pulses may occur after heavy rains and/or floods.
Plastic	For all estuaries and zones, there is no quantitative data on how much of an issue this is and also if plastic pollution causes any ecological effects. At the workshops the potential impacts issue of plastic nurdles was discussed but no data exist to assess the presence hereof in the estuaries.
Sewage	Possibly leachate from septic tanks and from stormwater: bordered by pastures, smallholdings and some residential areas may impact estuaries but no data are available. Not sure this is an issue for the outer zone due to flushing, WQ generally ranked as excellent at the heads of estuaries.

Nitrogen & Phosphorus	No data but likely runoff from agriculture in the catchment and adjacent areas.
Pesticides including PCBs	No data but likely runoff from agriculture in the catchment and adjacent areas.
Herbicides	No data but likely runoff from agriculture in the catchment and adjacent areas.
Oil or oil products	Likely runoff from adjacent roads through storm water and possibly from recreational boats.
Acoustic discharges / guns	NA
Electromagnetic discharges from cables	NA
Increased freshwater input from stormwater	This is a likely occurrence in all estuaries and for all habitats but no data exists so a low certainty was scored,
Endocrinal disrupters	This is may occur in all estuaries and for all habitats but no data exists so certainty was scored at “none”
Aquaculture	
Benthic accumulation of shells, food, faeces	Only applies to Mahurangi estuary
Change in primary production	Only applies to Mahurangi estuary
Increase in habitat complexity	Only applies to Mahurangi estuary

Fishing displacement from spatial closures: This applies to the intertidal oyster racks in Mahurangi estuary

Invasive species:

Space occupiers/competitors	For all estuaries and most habitats the species were the same: Oysters, *Crassostrea gigas,* the invasive mussel *Theora lubrica* present in low tidal and subtidal mud areas with greatest abundance. The tunicate *Styela clavata* is a possibility as it has been recorded in other areas near the assessed estuaries , and has spread very quickly - unsure if it establishes on mangroves.
Predators	goby (*Arenigobius bifrenatus*)
Grazers	NA
Toxic species	NA
Disease	The OsHV-1 *virus* impacted the oyster farms in Mahurangi in late 2012 - early2013. For this estuary it was scored as a threat on an occasional basis with low certainty

Shipping:

Animal strikes	Mammals do enter some of the estuaries so there is a small threat for animal strikes. Dolphins and killer whales have been seen in Whangateau. Where this threat has been

	scored, certainty is low.
Underwater noise	NA
Ship grounding, sinking	NA
Ecotourism:	
Marine mammal watching	Applies with some certainty to Whangateau only
Diving	
Trampling	Only where access has been identified in Google maps
Surface noise	NA
Changes in fish & invertebate behaviour	NA

Algal blooms - both toxic and massive: No data and thus certainty and impact has been scored as low

Turbidity : most habitats have been scored as persistently turbid over an area of 11- 25%, with a minor impact and low certainty as there is no data on turbidity measures

Anchoring: Only where identified in Google maps

Vehicle: Only where access has been identified in Google maps